CEP

CHEMICAL ENGINEERING PROGRESS

APRIL 1960

Processing fuels for the future

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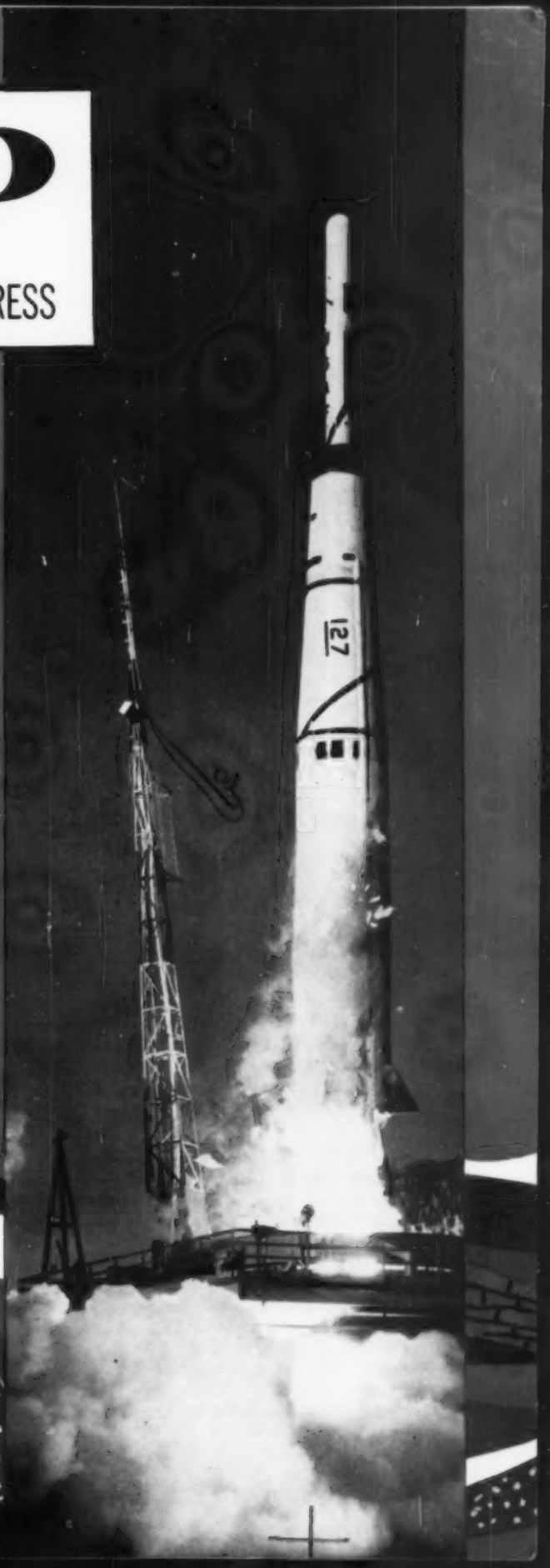

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April 1960 Volume 56, No. 4

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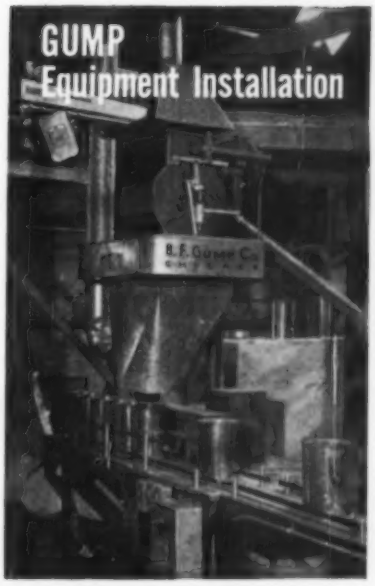

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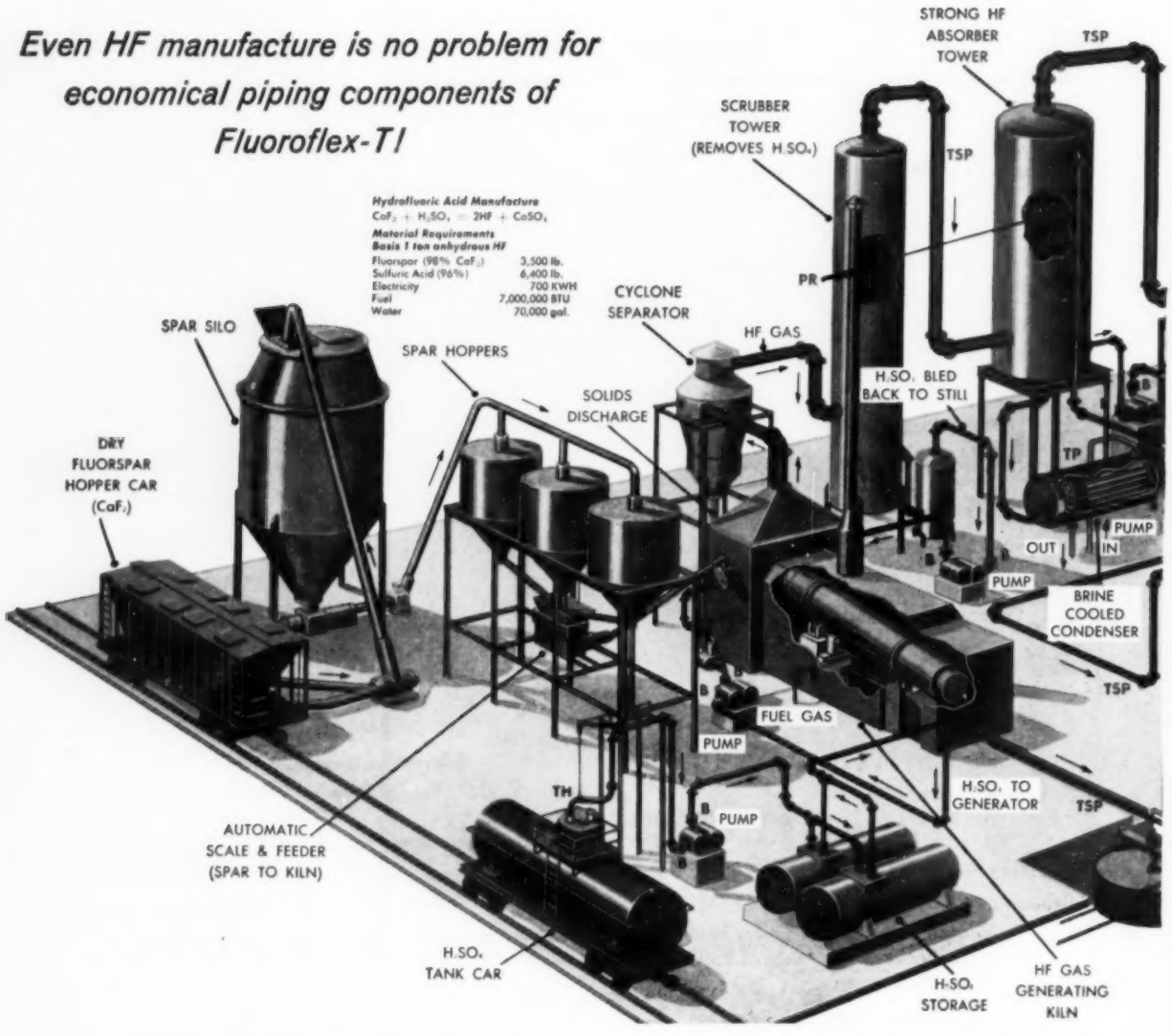

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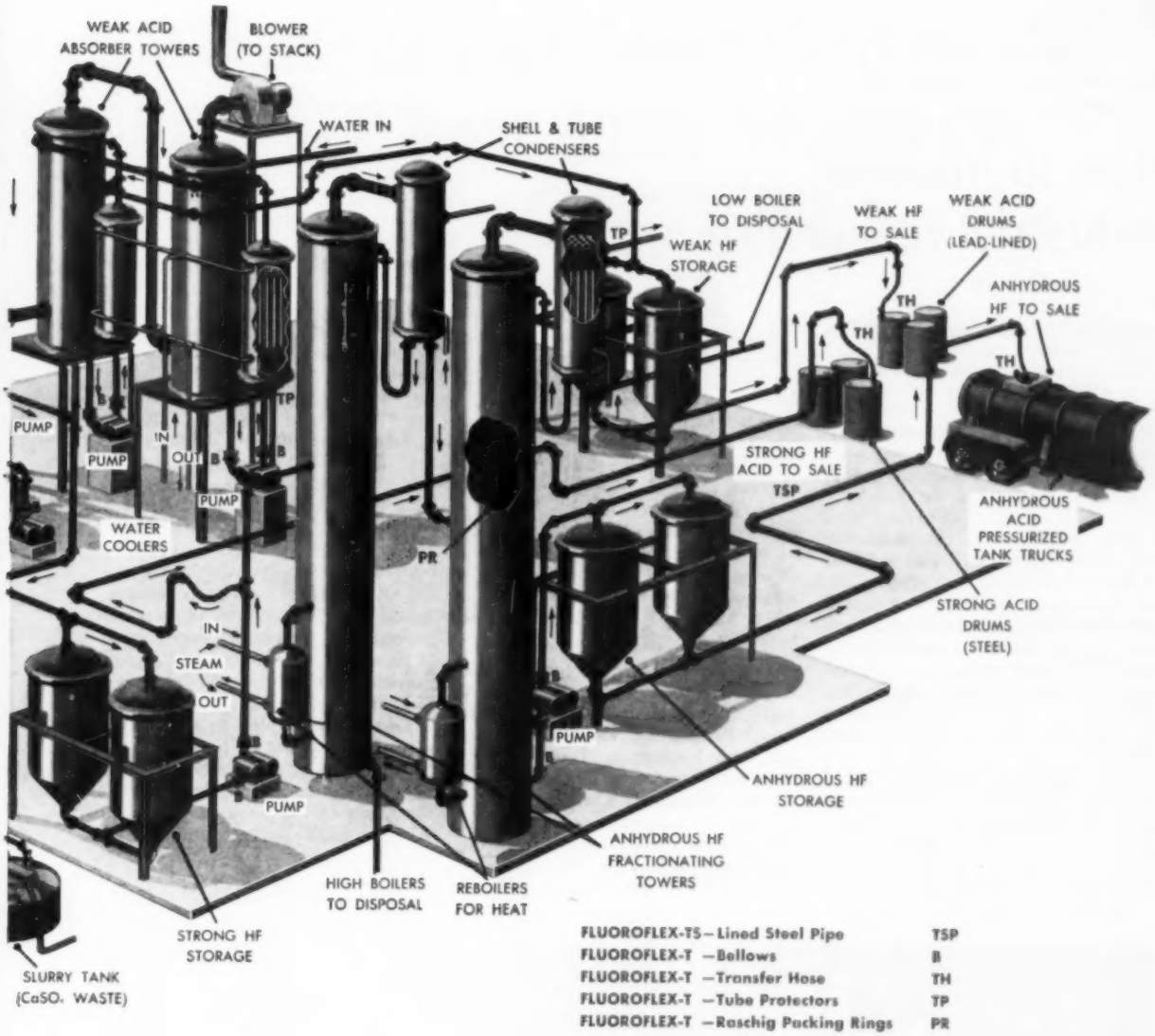

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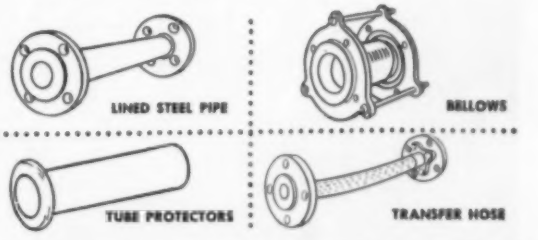

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book reviews

How to manage industrial research projects

HANDBOOK OF INDUSTRIAL RESEARCH MANAGEMENT, Carl Heyel, Editor Reinhold Publishing Corp., New York, N. Y. (1959), 513 pages, $12.00.

Reviewed by C. G. Kirkbride, Executive Director, Research & Engineering Dept., Sun Oil Co.; President, AviSun Corp.

This volume is a comprehensive and much needed review of the best of current thinking and practices in the operation, evaluation, and control of a research organization. Emphasis has been placed on a practical discussion of means and devices for solving problems in these areas. The editor has woven the contributions of 33 authorities into a well-organized text. It covers many subjects adequately enough to meet the needs of those not wanting an exhaustive treatment of any particular phase of research management. An index is provided which should greatly increase the usefulness of the material covered.

This is a book to be studied thoughtfully, rather than read. Some few sections are controversial, and there is an occasional overlapping of material covered, as is to be expected in a book of this type. This book is highly recommended, however, for those needing a general review to a particular area of research management, or a quick reference to a particular technique or tool in a specific field. It will be of less interest to someone making an intensive study of a particular problem, especially since references to other published work have been largely omitted.

The 17 chapters comprising this book have been grouped into five parts: Management Perspectives; Research Perspectives; Accounting, Control, and Evaluation; Personnel Administration in Research; and Research for Governmental Agencies. Part I treats of the broad aspects of research, management's objectives and the meshing of objectives with corporate goals, and the evaluation of research effort. Organization for research is discussed in a somewhat superficial and perhaps controversial manner. Essential elements for productive basic research are outlined, as are the advantages offered by outside research agencies. The final chapter presents a good summary of pertinent facts research personnel should know about the patent system and the protection of proprietary information.

Part II begins with a well written chapter on the establishment of research projects. Here, as in many places throughout the book, an appendix is included illustrating specific means of dealing with special problems—in this case, a check list for new product development. Specific and worthwhile suggestions are included in subsequent chapters on the direction of research projects, administration, organization for information research and the use of electronic computers.

Part III contains three chapters on budgeting, cost accounting, the reporting of cost information to management, and the control of research expenditures. Practically every aspect of these functions are covered, though necessarily in a brief and condensed fashion.

Part IV is devoted to the recruitment and training of personnel, and to techniques of salary administration. These chapters are ideally suited to the needs of top management people who are seeking a better understanding of problems and techniques in these areas, or of persons about to undertake work in these fields.

This volume concludes with a short chapter reviewing generally the field of government contract research work. As with the other chapters, this one provides just enough detail to lead to an understanding of the area discussed.

C. C. Parlin (left) of the Camille and Henry Dreyfus Foundation, plans the Camille Dreyfus Laboratory for polymer chemistry at North Carolina's new Research Triangle Institute with Research Triangle's president G. R. Herbert.

THERMODYNAMICS AND STATISTICAL THERMODYNAMICS, by J. G. Aston and J. J. Fritz, John Wiley and Sons, Inc., New York (1959), 556 pages, $8.25.

Reviewed by Thomas Baron, Head, Chemical Engineering Dept., Shell Development Co., Emeryville, Calif.

This excellent book has many good points, lucidity being among its strongest ones. It can be fully used, for pleasurable self-instruction or as a reference, without requiring any specific level of prior knowledge of the field.

This book is among the first in the field to combine in one volume a clear account of classical thermodynamics with a concise, yet fairly com-

continued on page 10

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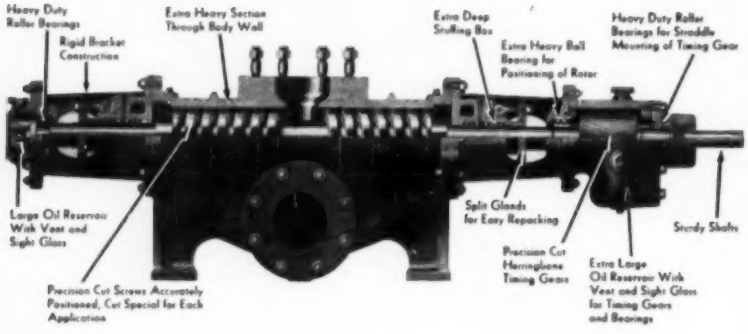
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Book reviews

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plete treatment of the statistical methods used for the calculation of thermodynamic properties of compounds in the ideal gas state. Enabling this combination is an admirably written chapter devoted exclusively to energy levels (Ch. 16), and a chapter dealing with the fundamental concepts and distribution laws of statistical mechanics (Ch. 17). The latter, and the final chapter (Ch. 23) form a good introduction to the general principles of statistical mechanics, and, together with a brief account of generalized thermodynamics (Ch. 9) they include sufficient background for the understanding of the thermodynamic methods of J. Willard Gibbs.

A variety of peripheral subjects is treated concisely, for example, the discussion of gravitational, electrical, magnetic, and surface effects (Ch. 15). A few subjects are given rather scant treatment—those on the activity of nonelectrolytes and on equations of state. To the practicing engineer, and particularly to one in the oil industry, these subjects never seem to get the attention they merit.

In all, this is a carefully written book, with a good deal of consideration given to the needs of the reader: Repetitions occur in strategic places, the discussion of new subjects is where possible preceded by a clear exposition of the main concepts, and a large number of problems, half of them numerical, is given. In short, were this reviewer still teaching, he would certainly choose this book for a text.

PROGRESS IN CRYOGENICS, Volume I. Edited by K. Mendelssohn, Academic Press, Incorporated, 259 pages, $11.00.

Reviewed by: H. M. Barry, Linde Co., Division of Union Carbide Corp.

This first volume contains nine excellent reviews of widely varying topics from the field of cryogenics. The volume has an international flavor, the authors being American, British, and Russian. Each article is critical and fundamental; and each is thoroughly referenced. The volume belongs on the bookshelf of every cryogenics laboratory library.

Several chapters are of interest to chemical engineers. In particular, "Distillation at Low Temperatures" is excellent. The difficulties involved in attempting to determine point efficiencies and, in general, the difficulty

continued on page 12

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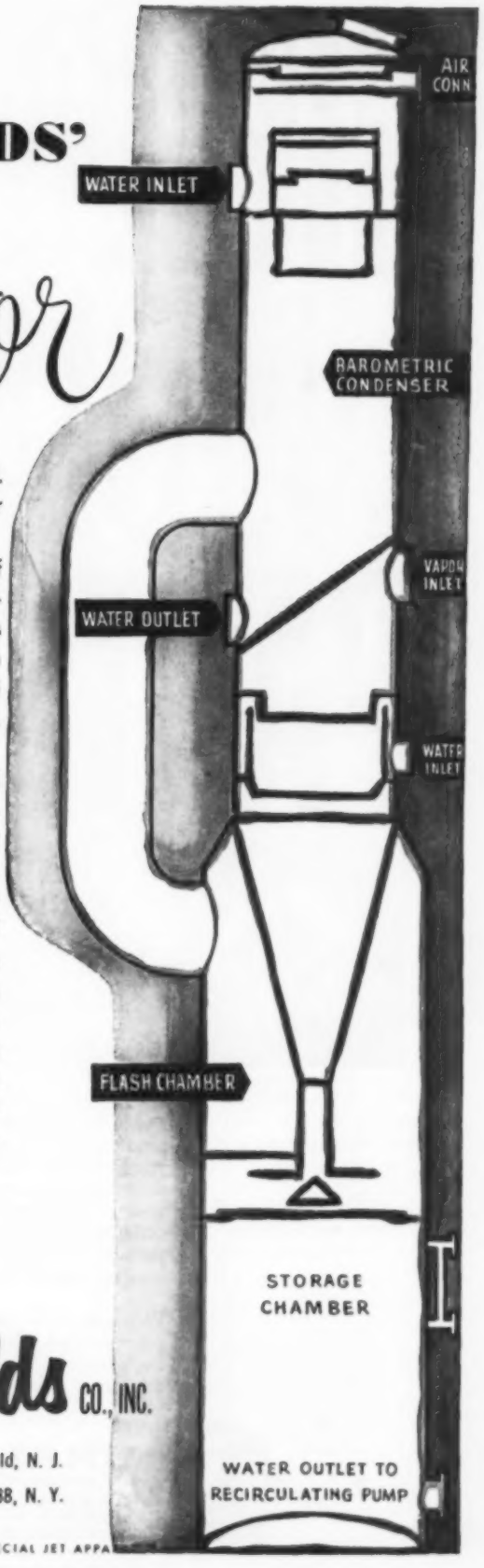
Patent applied for



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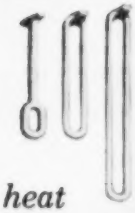

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Book reviews

from page 10

of gathering data in low temperature systems points out clearly that a great deal of research remains to be done before the performance of low temperature distillation systems can be predicted with some assurance.

Two other chapters which will prove useful to the chemical engineer are: "Evacuated Powder Insulation for Low Temperatures" and "Frozen Free Radicals."

This first volume has obviously been written with the research worker in mind. This plus the fact that some of the chapters are on subjects so far afield from chemical engineering (e.g. "Ultrasonic Attenuation in Metals at Low Temperatures") will probably not make the series popular with the chemical-engineer-at-large.

BRIEF COURSE IN ORGANIC CHEMISTRY, 2nd edition, L. C. Behr, R. C. Fuson, and H. R. Snyder, John Wiley & Sons, Inc., New York, N. Y. (1959), 289 p., $5.75.

MEDICINAL CHEMISTRY, Volume IV, Wilbur J. Doran, John Wiley & Sons, Inc., New York, N. Y., and Chapman & Hall, Limited, London (1959), 334 p., $12.00.

ORGANIC SEQUESTERING AGENTS, Stanley Chaberek and Arthur E. Martell, John Wiley & Sons, Inc., New York, N. Y. (1959), 616 p., $25.00.

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PROCEEDINGS OF THE AMERICAN SOCIETY FOR ENGINEERING EDUCATION, Volume 66, 1958-59.

THE STRUCTURE & PROPERTIES OF POROUS MATERIALS, (Proceedings of the Tenth Symposium of the Colston Research Society held at the University of Bristol, (1958), Edited by D. H. Everett and F. S. Stone, Academic Press, Inc., New York, N. Y. (1959), 389 p., $12.00.

A $2 million expansion of the ammonia, urea, nitric acid, and nitrate facilities at Solar Nitrogen Chemicals' Lima, Ohio plant is moving ahead. Annual increase in ammonia production of about 25,000 tons per year is anticipated. Firm is jointly owned by Atlas Power and Standard Oil of Ohio.

Continual expansion of the processing industries demands equipment designed and developed for *today*. Our MIKRO-BUD is an example of this type of planning. Recent changes in this vertical hammer mill were dictated by field tests on a variety of materials including cocoa, rubber accelerators, sodium sulphate, sugar, phenolic resins, dyes, colors and tobacco. Capacities have been stepped up from 40 to 100 per cent, depending on the material in process. Efficient air flow has added to the range of heat-sensitive materials handled without coolants. A selector control wheel allows adjustment over a wide range of particle sizes without shutting down the mill. Write for Bulletin 51-C-1.

The MIKRO-BUD is one of four different designs and 12 sizes of Mikro pulverizing equipment offering grinds from granular to the lower micron ranges, and capacities up to 20,000 lbs/hr on certain materials.

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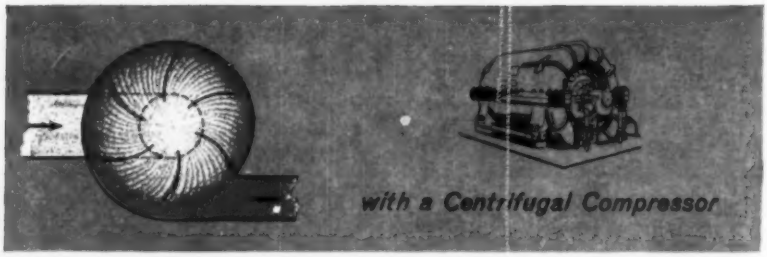
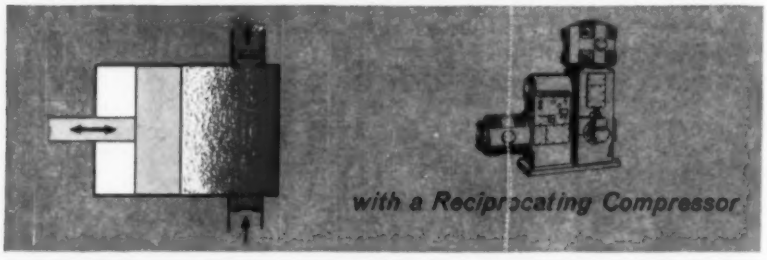
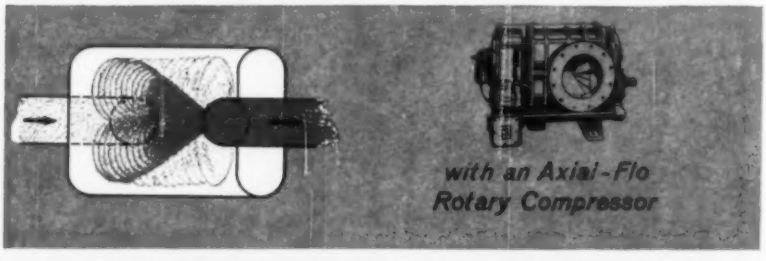


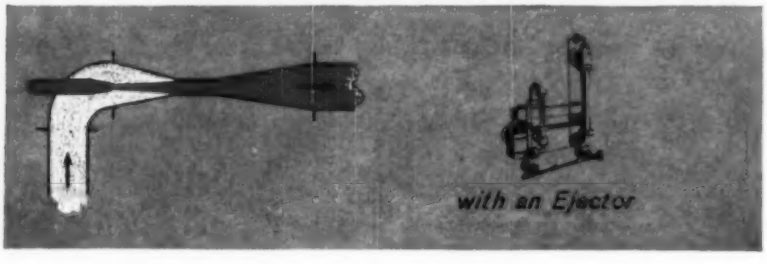
PUSH IT



SQUEEZE IT



PULL IT



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The threshold of life—or death

Hope seen for survival of human race, despite air pollution, radioactive fallout, other toxicological effects of a technology-based civilization.

"IF IT WERE NOT TRUE that the body can cope with sufficiently small doses of toxic chemicals, the human race would have perished long ago," said J. A. Zapp, Jr., of Du Pont's Haskell Laboratory for Toxicology and Industrial Medicine. Zapp spoke at the recent President's Conference on Occupational Safety in Washington, D. C.

Almost all our food and water contains small amounts of lead and arsenic, continued Zapp, while in our automobiles and houses there is almost always a small amount of carbon monoxide originating from incomplete combustion of fuels. Burnt toast and charred meat, he pointed out, contain traces of well known carcinogens and, in recent years, strontium-90 has appeared in many foods including milk.

Is all radiation harmful?

What are the consequences of this point of view applied to the present much publicized problems of air pollution and radioactive fallout? "Experimental toxicology," according to Zapp, "has demonstrated that, in experimental situations, the toxic effects of a given material will disappear at some sufficiently small *but still finite* dosage level." In every experimental study of toxicity, he says, it has been possible to select doses so small that no harmful effect occurs even when the material is administered over the entire life span of the experimental animals. This includes even the chemical carcinogens.

The fly in the ointment

Key problems is the estimation of safe intake levels for man by extrapolation of data obtained on non-human species or from observation of man in his environment. "It seems entirely reasonable to suppose," says Zapp," that if man were the experimental animal in the laboratory, a safe level of intake could be found for him also, although the experimental determination of this level would be extremely difficult because the experimental period might have to cover his entire life span. (Such experiments would be, incidentally, illegal)."

Applying the same reasoning to the problem of air pollution by automobile exhaust fumes, Zapp states that, while this particular problem could be solved by banning the automobile, it will not be solved in this way because automobiles are now an essential part of our economy. The problem, he says, is insoluble if one postulates that *no* level of automobile exhaust fumes is harmless. It is soluble, however, if one can agree that some finite level can be tolerated without harmful effects.

Belgian chemical process know-how to USSR

Techmashimport, Soviet industrial agency, has contracted with Etudes et Recherches Industrielles of Brussels, Belgium, for design and engineering of plants for acetylene from natural gas and for ammonia. Licenses for the two processes have been granted by Societe Belge de l'Azote et des Produits Chimques du Marly, Liege, Belgium, which will handle design, engineering, and equipment supply.

First positive auto exhaust control measure in L.A.

The Automotive Industry says that, starting with their 1961 models at the latest, all cars offered for sale in California will be equipped with an inexpensive device to prevent emission of crankcase vapors. These vapors, called "blowby", will be fed back into the cylinders and burned. Both the County and City of Los Angeles have ordered installation of similar devices on County- and City-owned vehicles. However, the Air Pollution Foundation emphasizes that this is only the first step—blowby accounts for only 10-20% of the L. A. smog problem, complete smog elimination must await adoption of afterburners to control tailpipe exhaust.

Import threat seen in synthetic fibers

In a plea for more tariff protection, American Viscose's H. L. Dalton points out that during 1959, more than 115 million pounds of rayon staple were shipped into the United States by foreign suppliers—a 40% increase over 1958's 83 million pounds. "This," says Dalton, "is the equivalent output of two average-sized American plants and it means that foreign imports of rayon staple have taken over 25% of the domestic market."

SCOPE

continued

Gas-light concepts spark energy studies

Revived interest in 19th century theories translated into direct fuel-power conversion devices with increased emphasis towards fuel cells, thermoelectricity, thermionics, and magnetohydrodynamics.

A SPACE AGE CONCEPT in small-scale power generation is actually back pedaling towards direct power conversion systems. It's a story of the old supplanting the conventional, since these new techniques—fuel cell, thermoelectricity, thermionics, magnetohydrodynamics—are based on Gas-Light theories that have become promising with recent technological advancements. The big appeal is their high efficiencies obtained in side stepping the heat cycle in developing electrical energy.

Immediate uses of these processes appear to be in small-scale power units where unlimited numbers of applications can be developed, particularly in military and space projects. However, development of new materials to operate efficiently at high temperatures could also make these techniques competitive for large-scale central power stations in their ultimate applications.

A survey of industry shows an intensive research program being undertaken in each of these energy conversion processes. Here's the present status of each.

Fuel Cell

This is an electrochemical device which converts the free energy of a chemical reaction directly to electrical energy, avoiding the Carnot cycle limitations of heat engines. Theoretical efficiency approaches 100%, with present models obtaining 70-80% efficiency.

There are several types of fuel cells at present, differing in their fuel, oxidant, electrolyte, catalyst, and temperature of operation. Low temperature cells operate best using H_2 and O_2 with either an aqueous or ion exchange membrane electrolyte. Cheaper fuels along with air are being tested in high temperature cells using molten salts or solid electrolytes. Table 1 compares several types of fuel cells with other conversion systems.

The fuel cell is being considered as a small power unit for many devices. It may also find application as a storage battery in combination with solar energy converters.

The high temperature cells introduce materials problems, especially in the electrodes and electrolytes. Materials research in fused salts, special ceramics, and metal alloys has been undertaken to improve fuel cell operation.

Table 1. Performance data of power converters.†

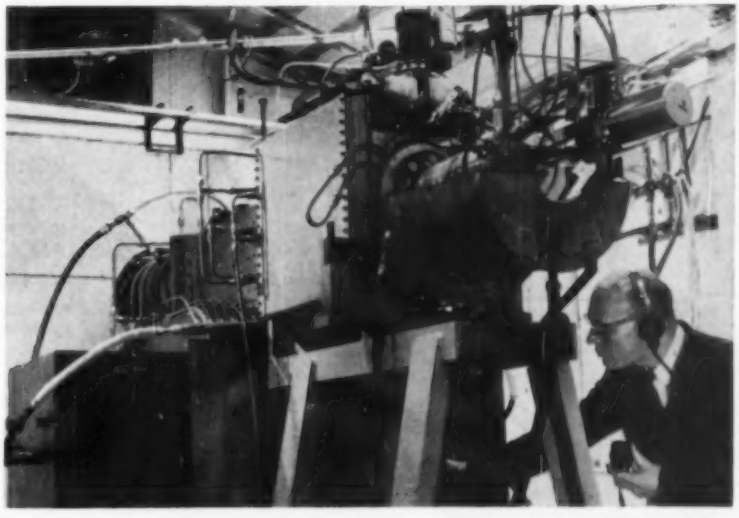
TYPE	MEDIUM	TEMPERATURE	ESTIMATED POWER
FUEL CELL			
H_2-O_2	Aq. alkaline (50 atm.)	200-240°C	2.0-4 kw/cu. ft.‡
H_2-O_2	Solid ion exchange membrane (1 atm.)	Ambient to 50°C	1.5-3 kw/cu. ft.‡
H_2-air	Aq. alkaline (1-5 atm.)	50-80°C	.2-1 kw/cu. ft.‡
H_2-air	Aq. chemical intermediates (redox) (1 atm.)	Ambient to 80°C	.2-2 kw/cu. ft.‡
Carbonaceous materials-air			
Cabronaceous gases	Molten salt (1 atm.)	500-850°C	1.0-4 kw/cu. ft.‡
THERMOELECTRIC			
8-10% eff.	Typical junction: p and n type PbTe	427-527°C	10-50 lb./kw
THERMIONIC			
4½% eff.	Vacuum	1100°C	25 lb./kw
17% eff.	Gas filled	1900°C	4 lb./kw
MAGNETOHYDRODYNAMIC			
.....	plasma	2760°C	.....
CONVENTIONAL			
Steam-Turbine			200 watts/lb.
Storage Battery			1.0-2 watts/lb.

† *Data obtained from Westinghouse, General Electric, and other industrial sources.*

‡ *Values are for cell only.*

Thermoelectricity

Here is another area that is being considered for specialty power generation projects, particularly since new materials have recently increased its efficiency. This technique is based on the Seebeck effect discovered in 1821 when heat applied to a junction of two conductors was found to produce a small current in a connected circuit. Recent advances in semicon-



Experimental magnetohydrodynamic power generator built by Westinghouse for operation in the kilowatt range.

ductors has allowed the adjusting of material properties to operate a device at an optimum efficiency.

Generators of 100 watts are available now with capacities of 5000 watts expected shortly. Advantages of this generator are that it is compact, silent, has no moving parts, and its efficiency is independent of size. Thermoelectric materials have shown efficiencies to 17%, but overall conversion efficiencies drop to 6-8% when operated in practical multiple units.

Thermoelectricity is presently being considered in conjunction with a variety of heat sources for power generation. Hydrocarbon fuels and radioisotopic heat as in Martin's SNAP-3 generator are presently used; the heat of fission in a nuclear reactor is being considered.

Increased efficiency can be obtained by developing materials to operate at higher temperatures, better device design, and better utilization of the heat source. Present materials are applicable to 600°C, newer mixed valence materials, such as samarium sulfide, operate at 1100°C. Modified insulator materials (pure nickel oxide doped with 3% lithium) are also being considered.

Thermionic Converter

Another promising power converter is the thermionic generator, which until very recently has not been explored because of materials problems. This device operates at high temperatures with electrons being emitted from the hot cathode into either a vacuum or an ionized gas space and collected at the anode. Primary problem is to find materials with high heats of vaporization and with low work functions to operate at temperatures of 4500°F for long periods of time.

Applications and features of these devices are similar to thermoelectric devices.

Magnetohydrodynamics

An MHD generator, based on Faraday's Law, passes a hot, ionized gas called a plasma at high velocities between the poles of a magnetic field where electrons are deflected towards an electrode in the flow stream.

Westinghouse recently claimed to operate the first MHD generator of appreciable size for producing electric power from combustion of conventional fuels. The generator produced 2½ kw. of power, operated at 25% of rated capacity, and ran continuously for 4 min. as compared with previous runs of about 5 sec.

MHD is being considered for large power applications, and overall thermal efficiencies of 60% are predicted. Another potential application is for space propulsion where Westinghouse proposes to reverse the cycle and use electrical energy to increase plasma motion for propulsion of space ships.

Other items of interest related to energy conversion that have recently been announced are:

Conversion of heat directly to alternating current in a high temperature cesium cell by General Dynamics Corp.

Increased efficiencies of solar batteries to 15% for direct conversion of solar energy to electrical power have been reported by Bell Labs.

The wild blue yonder

The blue haze seen over the world's vegetated areas may actually be petroleum in the process of formation, according to a hypothesis advanced by F. W. Went of the Missouri Botanical Garden, St. Louis. According to Went, the blue haze is actually a layer of asphaltic and bituminous particles created by hundreds of millions of tons of volatile hydrocarbons and near-hydrocarbons expelled into the atmosphere annually by living plants. These particles eventually rain down on earth and, in time, form petroleum.

One of the Garden City Fan installations in Stark Ceramics, Canton, Ohio

The beautiful structural glazed facing tile (in fashion-right colors) from Stark Ceramics is rated top quality by tile experts everywhere. It is therefore a matter of pride to Garden City that this respected company prefers Garden City high temperature Thermal-Aire Fans on their kilns.

These sturdy fans perform at temperatures up to 1300°F. in the Stark Ceramics installation. Their design is "tailored" to specific user requirements: construction materials are carefully selected to withstand the user's operating temperatures. Air-Cooled Shafts protect bearings against heat. Result: low maintenance cost; long service life.

Hundreds of "Blue Chip" companies like Stark Ceramics are sold on Thermal-Aire Fans. Find out more about them for *your* high temperature applications to 1850°F.

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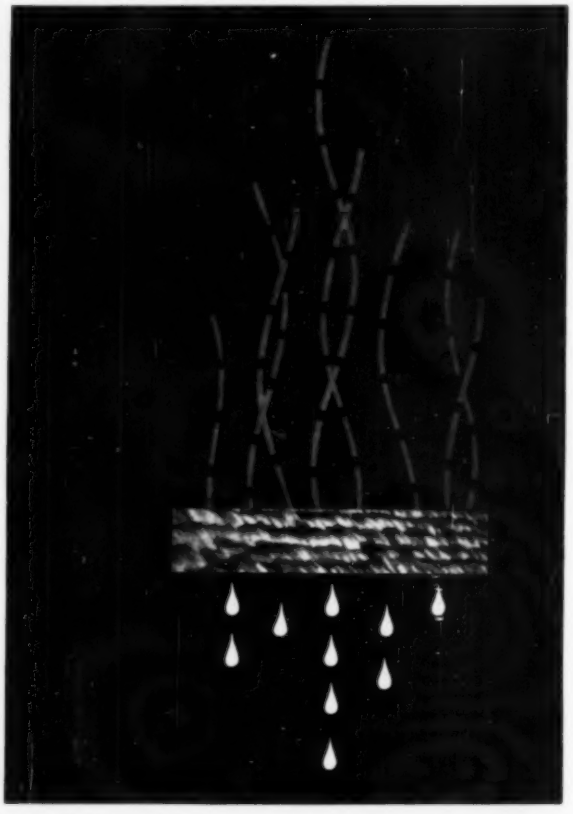

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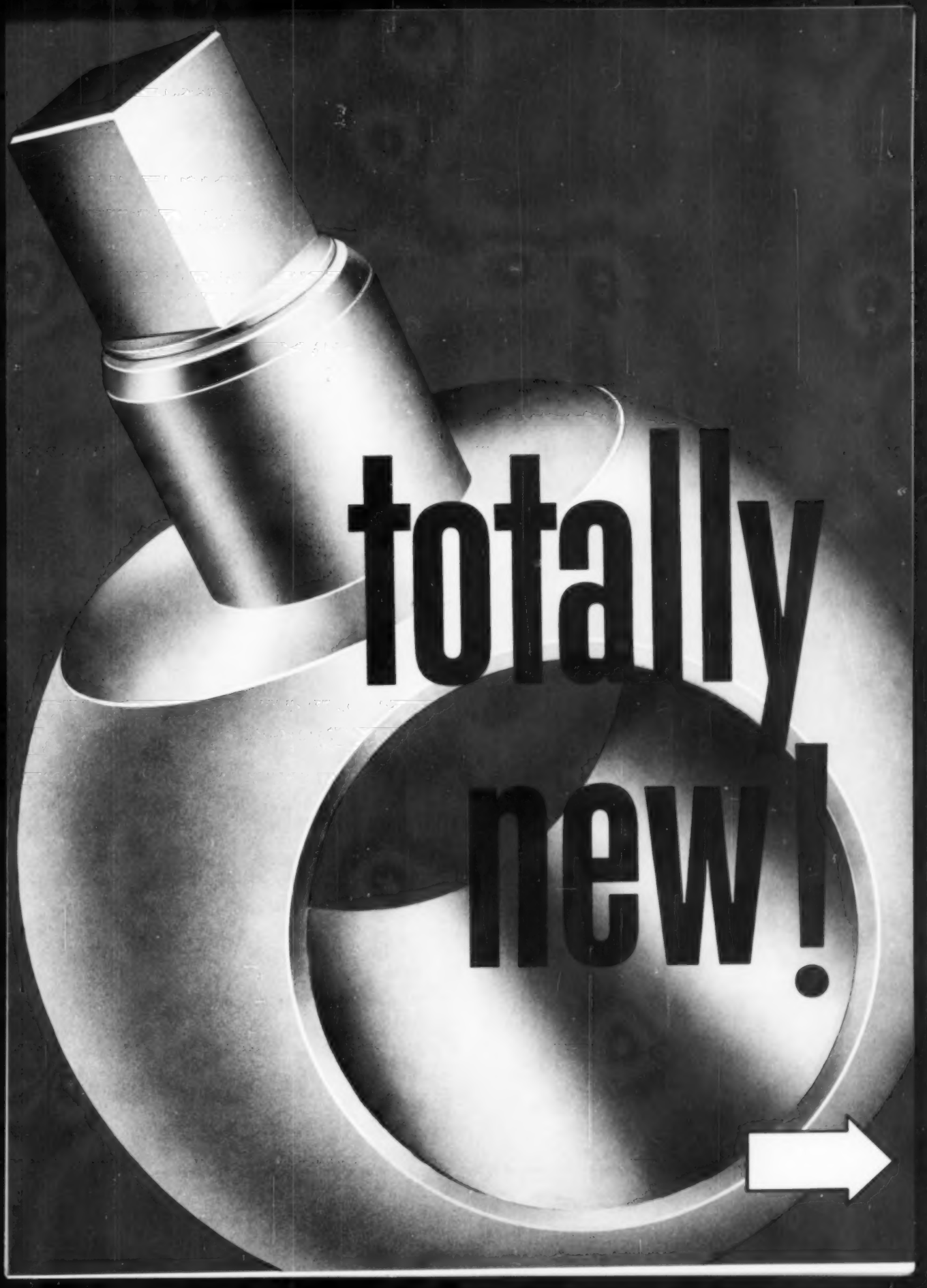
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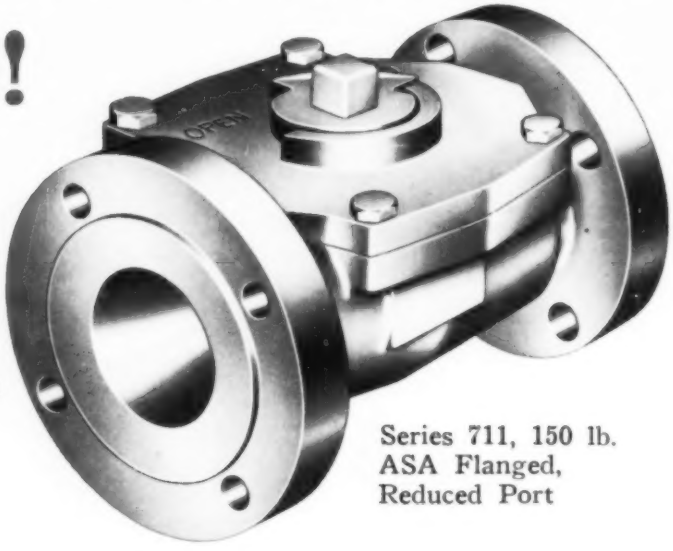
Only *FLO·BALL* valves are bearing-fixed for maintenance-free long life!

. . . with all the features you must have:

- **Top loading**
- **Replaceable seats**
- **One-piece ball and stem**
- **90° on-off**
- **Two-way flow**



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Now available . . . the result of years of intensive service in the missile-space industry . . . proven in thousands of adverse applications . . . now at mass produced prices . . . the most advanced line of ball valves ever manufactured . . . for you!

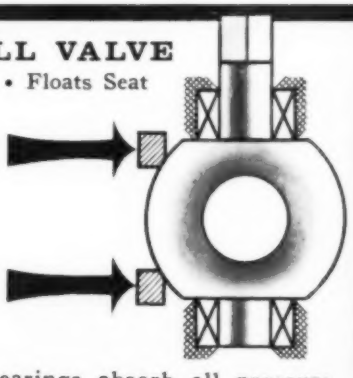
ORDINARY BALL VALVE

Floats Ball • Fixes Seat

Floating ball puts excessive pressure load on fixed seats. Results in distortion and short life.

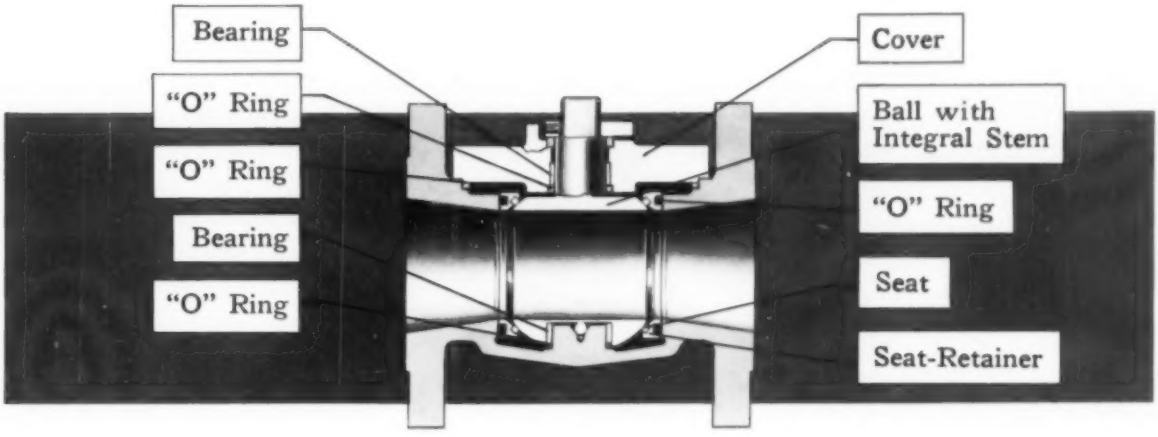
FLO • BALL VALVE

Fixes Ball • Floats Seat



FLO·BALL bearings absorb all pressure forces. Elimination of excessive seat loading insures long life.

The Series 711 ***FLO·BALL*** valves are available for off-the-shelf delivery. Manufactured to standard ASA dimensions in carbon steel, 316 stainless steel, and aluminum for body and ball, Teflon for seats, and Buna "N" O-Ring seals. Other materials are also available. These valves operate at pressures to 300 psi, temperatures to 400° F.



The Hydromatics Series 711 FLO•BALL valve gives you the features you must have!

- Bearing-Fixed ball. Engineered to withstand shock and impact without distortion or backlash.
- Top loading. Valve can be disassembled and assembled without removing it from line. No special tools are required.
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- Zero leakage. At all operating pressures, including vacuum to 10^{-6} mm. of Hg.
- One-piece stem and ball. Simplified construction adds strength, precision and lower torque.
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Maximum flow

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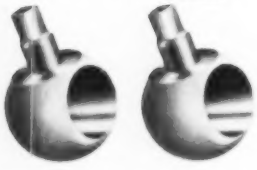
New



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letters to the editor

Trademarks–Upper Case

In reviewing the February, 1960 issue of your magazine, I noted the improper usage of Dorr-Oliver Inc. registered trademarks in connection with Mr. Sommers' article beginning on page 76, and particularly in Figure 1 on page 77.

Both "Dorr" and "Dorr Thickener" are trademarks registered by Dorr-Oliver Inc. in the U. S. Patent Office. As you probably appreciate, if we permit these marks to be used in generic senses rather than indicating origin of goods, there is the chance that we might lose our exclusive rights to these names in time. This fate we are most anxious to avoid as we consider these marks to be most valuable assets.

We would greatly appreciate it if you could keep this in mind for future articles. If you desire to refer to our trademarks, please capitalize the initial letters and append a footnote explaining that "————— is a Registered Trademark of Dorr-Oliver Incorporated."

PHILIP MINTZ

Legal and Patent/Dept.
Dorr-Oliver, Inc.

Pardon a slip in processing the article in which we did not catch the lower case used in the flow sheet. Upper case, as was used in the body of the text, is always proper when referring to trademarks. This is standard editing procedure. Use of a footnote as suggested is impractical–Ed.

Which Houdry?

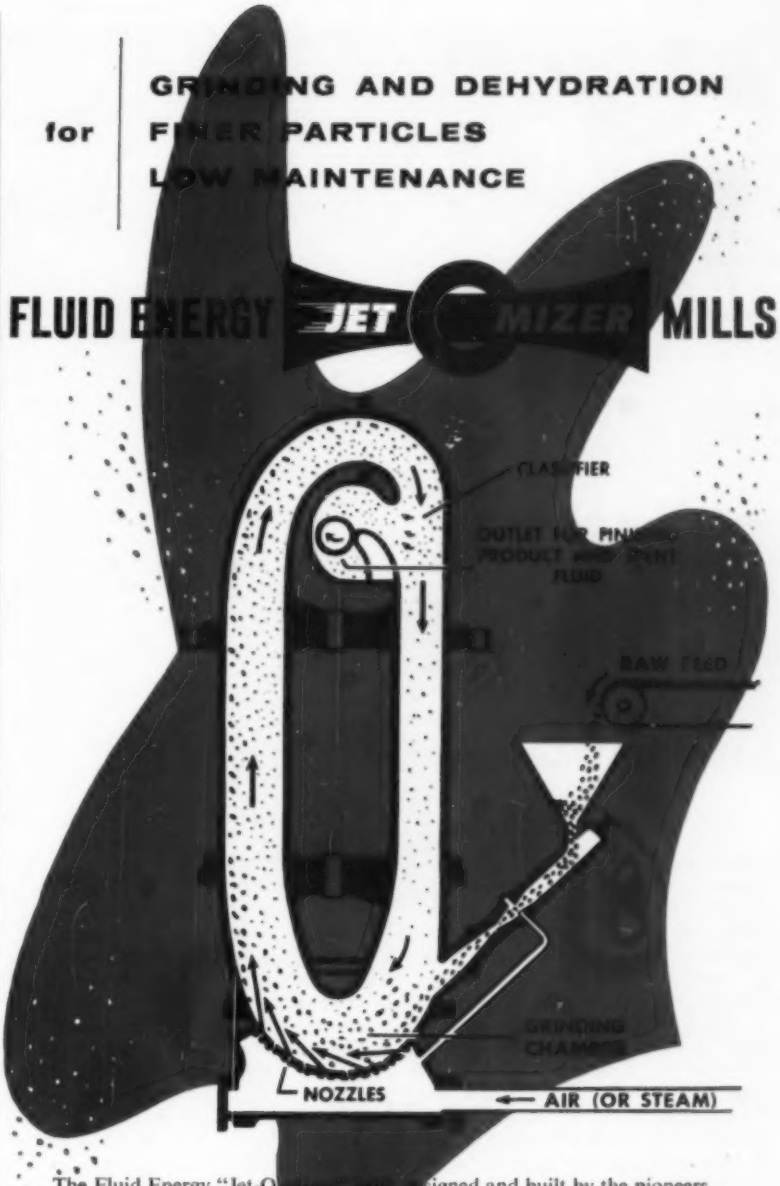
A note in your January, 1960 issue dealing with auto exhaust control devices contains the phrase, "Houdry's catalytic converter."

The use of the word "Houdry" in this connection has caused considerable confusion and we would like to bring to your attention the facts surrounding the situation. This catalytic converter was developed by Mr. E. J. Houdry who is Chairman of the Board of Oxy-Catalyst, Inc. Years ago Houdry Process Corporation was founded by Mr. Houdry but for the

continued on page 26

for GRINDING AND DEHYDRATION FINER PARTICLES LOW MAINTENANCE

FLUID ENERGY JET-O-MIZER MILLS



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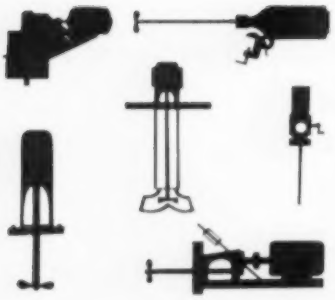

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Washington scope

Agricultural alchemy

SECRETARY OF AGRICULTURE BENSON'S recent quiet, but very important appointment of chemical engineer Roy Chester Newton to the newly created post of Coordinator of Utilization Research in the Dept. of Agriculture, has gone almost unnoticed in Washington circles. But it is most significant because of pending legislation. The appointment of the retired vice president of research of Swift and Co. may be the turning point in a controversy of several years' duration involving a chemical research program that could exceed $100,000,000 annually.

Strangely enough almost all of those involved in the agricultural surplus disposal problem agree that chemical research offers the best possibility of providing a solution, and almost all agree that research directed toward converting the growing stores of agricultural surpluses should be conducted under the auspices of the Department of Agriculture. But here agreement ends.

The Department of Agriculture wants to proceed by beefing up its current $16,000,000 a year pace, building upon the foundation long established by its four regional laboratories and ten field stations which currently employ 1600 researchers. The Department has asked for $18.4 million for this work in fiscal 1961. Opposing legislators, primarily in the Senate, are adamantly insisting on a "crash progam" headed by a consequential staff of top-flight scientists commanding salaries approaching $20,000 per year—far above the pay drawn by Department of Agriculture career men now engaged in such work. No one doubts the effectiveness of the Department of Agriculture's current program, but many feel that it is not nearly big enough to cope with the problem.

The Senate did pass a bill (S. 4100) in 1958 but too late for House action. An identical bill (S. 690) introduced during the present 86th Congress, has been passed by the Senate and sent to the House. Meanwhile H.R. 8639 has been passed by the House and sent to the Senate. Presumably the differences in these two bills, which embody the two points of view in this drawn-out deliberation, will be resolved in conference.

The House Bill (H.R. 8639), the one the Department of Agriculture prefers, calls for the creation of "an independent agency in the executive branch of the Government to be known as the Agricultural Research and Development Commission, which shall be composed of seven members appointed by the President, by and with the advice and consent of the Senate, who shall serve at the pleasure of the President."

The Senate Bill (S. 690), opposed by the Department of Agriculture, "establishes an agency to be known as the Agricultural Research and Industrial Administration *in the Department of Agriculture* (italics mine) to coordinate and expedite efforts to develop new uses for farm products, new crops to replace those in surplus., and additional means of disposal of surplus commodities in Government inventory."

Assistant Secretary of Agriculture Ralph S. Roberts told *CEP* that the Department of Agriculture prefers the House Bill H.R. 8639 because it would cost the taxpayers less money. But a list of the Department's objections (unsigned and undated) furnished by the House Subcommittee on Research and Extension cites many objections to S. 690.

It is obviously most important to the Department of Agriculture whether they have to deal with an advisory group under the President, or have thrust within their department a new agency with broad powers under the law to compel action and the funds with which to do it. Hence, the appointment at this time of a man of Roy Newton's stature for a period of six months to investigate the Department's present setup and report to the Secretary, seems highly important. Assistant Secretary Roberts emphatically states that Newton's appointment has nothing to do with the pending bills to stimulate utilization research. Be that as it may, this appointment should result in much good for the Department of Agriculture and for the nation.

—J. L. Gillman, Jr.

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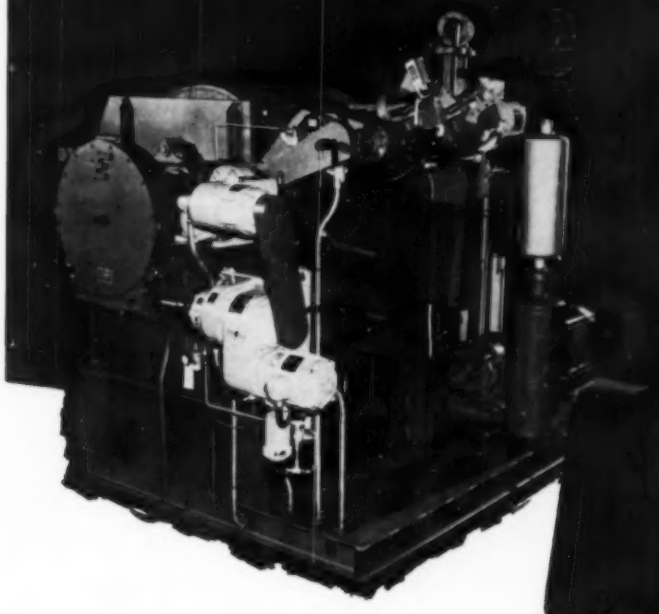

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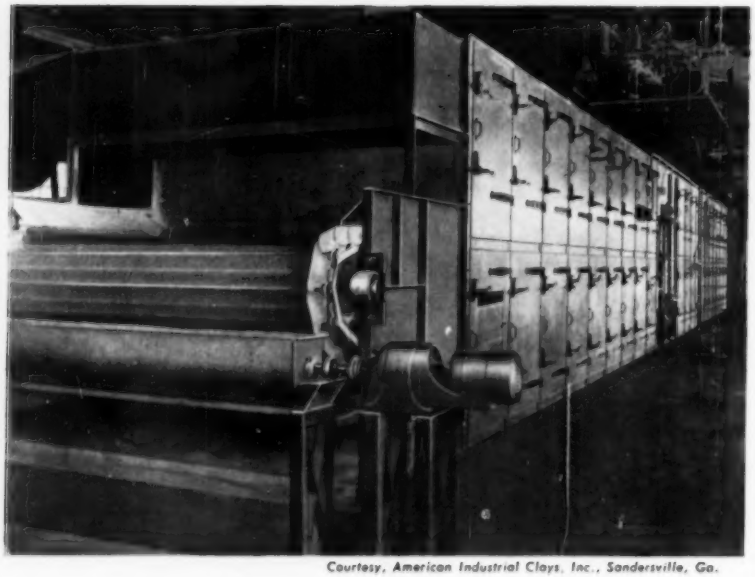

Courtesy, American Industrial Clays, Inc., Sandersville, Ga.

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Letters to the editor

from page 23

past ten years he has not been associated with us in any way. A large part of our business comprises the sale of various processes and catalysts under the Houdry label and through the years the words "Houdry" and "Houdry Company" have been commonly associated with the Houdry Process Corp. in the oil and chemical industries.

Naturally we are happy that Mr. Houdry is taking an active part in this new field but we do want to call your attention to the source of confusion in the use of the word "Houdry." We hope that with this knowledge you can avoid this in the future.

H. A. SHABAKER
Houdry Process Corp.

While the usage was grammatically correct in this instance, perhaps "Eugene Houdry's catalytic converter" would have avoided confusion—Ed.

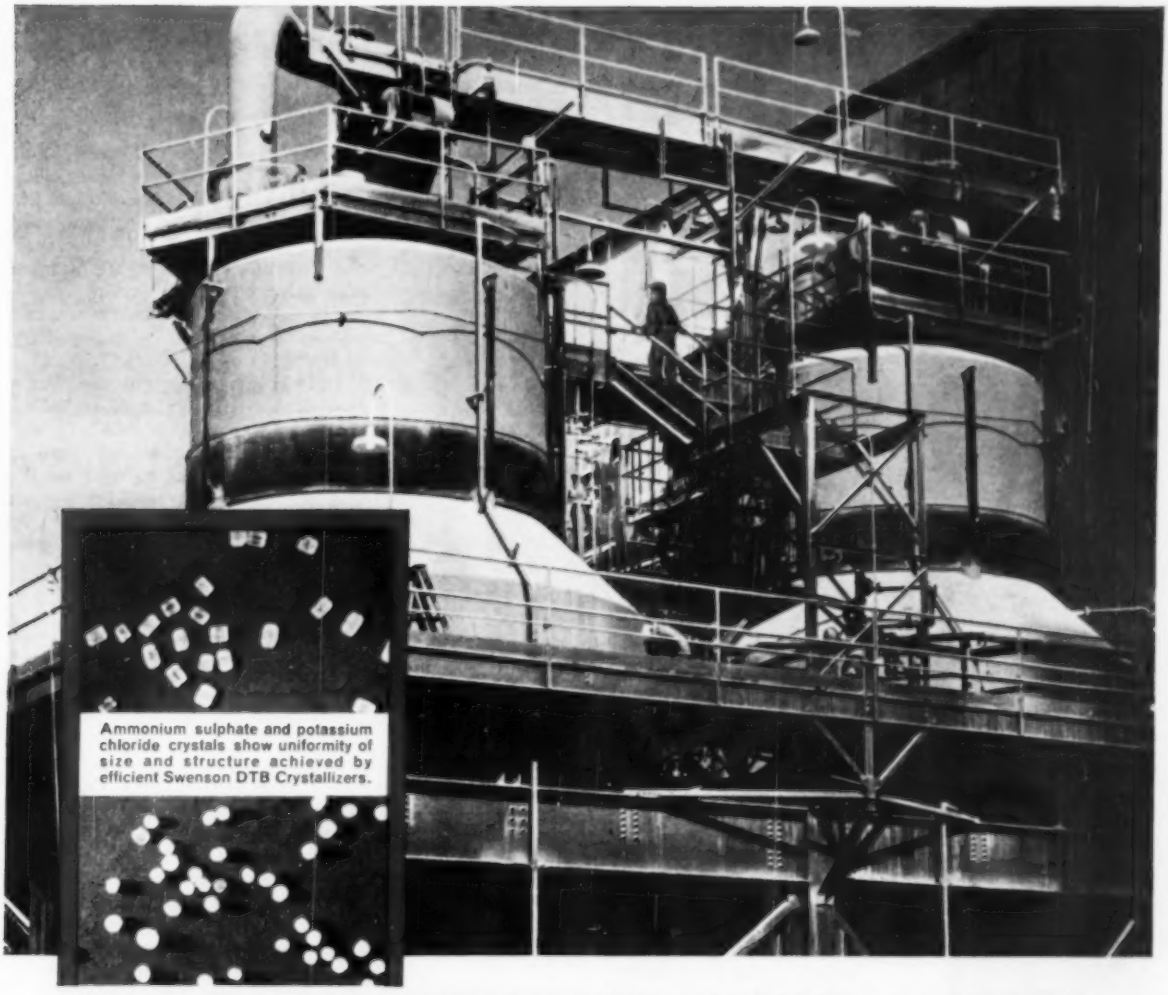
Coded articles?

For several years I have been "talking up" a program, although it would be a tremendous task to initiate. It would be to prepare a numerical code to identify technical articles, and to publish the code number of each article along with the title. As a matter of fact, if the master code were published, the author could be required to supply a code number as well as a title for any article submitted for publication.

A system of this sort would save a tremendous amount of time in making literature surveys, and a secretary or librarian could identify in current literature and select for a technical man exactly and all the articles he wished to review in this literature. With the greatly expanded volume of published matter that crosses our desks each week, it becomes almost impossible to pick up the articles in which you are particularly interested. These articles could surely be identified by a 10 to 12 or 14 number code, and a secretary could then be alerted to select articles for her supervisor which have only certain code numbers. Literature searching could be speeded up by the same process, and carried out in complete confidence by persons who would need to know nothing, themselves, about the subject material.

Further, abstracts might be printed

continued on page 28


Ammonium sulphate and potassium chloride crystals show uniformity of size and structure achieved by efficient Swenson DTB Crystallizers.

23 FOOT DIAMETER DTB CRYSTALLIZERS

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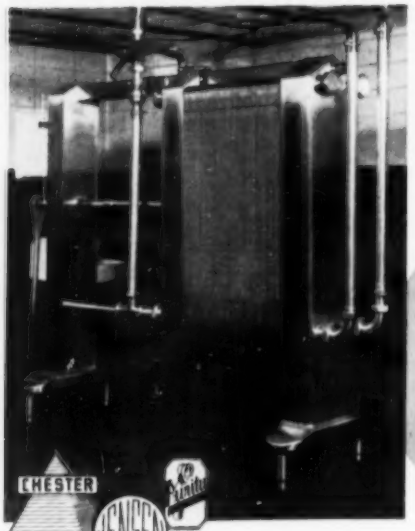
This CHESTER-JENSEN PLATE HEAT EXCHANGER



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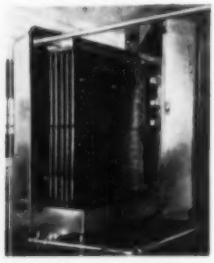

Fan Type "Beaudelot" Cooler, above, is one of five similar units built by Chester-Jensen for low temperature cooling of almost any liquid.

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Letters to the editor

from page 26

on cards, and the code designation cut in the same cards. Hence subscribers to such a service could receive blocks of coded cards to cover certain areas, or possibly all areas, and literature surveys could be completed by electronic sorting equipment. Other ramifications of such a project should also be immediately apparent.

I think such a program might have far reaching possibilities, and I see no particular reason why A.I.Ch.E. and CEP might not spearhead such a project. I would like to work on it—and, most of all, I would like your opinion.

B. E. Lauer

Head, Dept. of Chem. Eng.
University of Colorado
Boulder, Colorado

Work's in progress

I am glad to see another person who is interested in the problems of handling technical information in such a manner that it can be retrieved when particular needs arise. We have a subcommittee of the A.I.Ch.E. Standards Committee which was established about a year ago but has only begun to work within the last several months. This subcommittee has as its assigned task the problem of studying whether standard systems can and should be developed for the handling, indexing, and retrieving of technical information in the chemical engineering field.

In our first meeting of the subcommittee which was held last December, the consensus was developed that the first and most urgent need was the development of some kind of a thesaurus or word book giving the preferred chemical engineering terms and their synonyms and related terms. It was also developed at this meeting that the primary interest is upon the study of systems that would be readily useable in small organizations, such as an individual chemical engineer and his stenographer.

Considerable progress has already been made in the indexing and retrieval of technical information on large scales by each of several organizations. One of these organizations is my own company, du Pont, which has been actively studying the various outside developments and has placed in operation two moderately large

continued on page 30

BETTER THAN FILTERS
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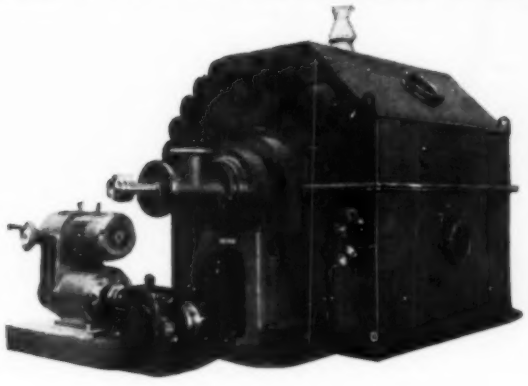

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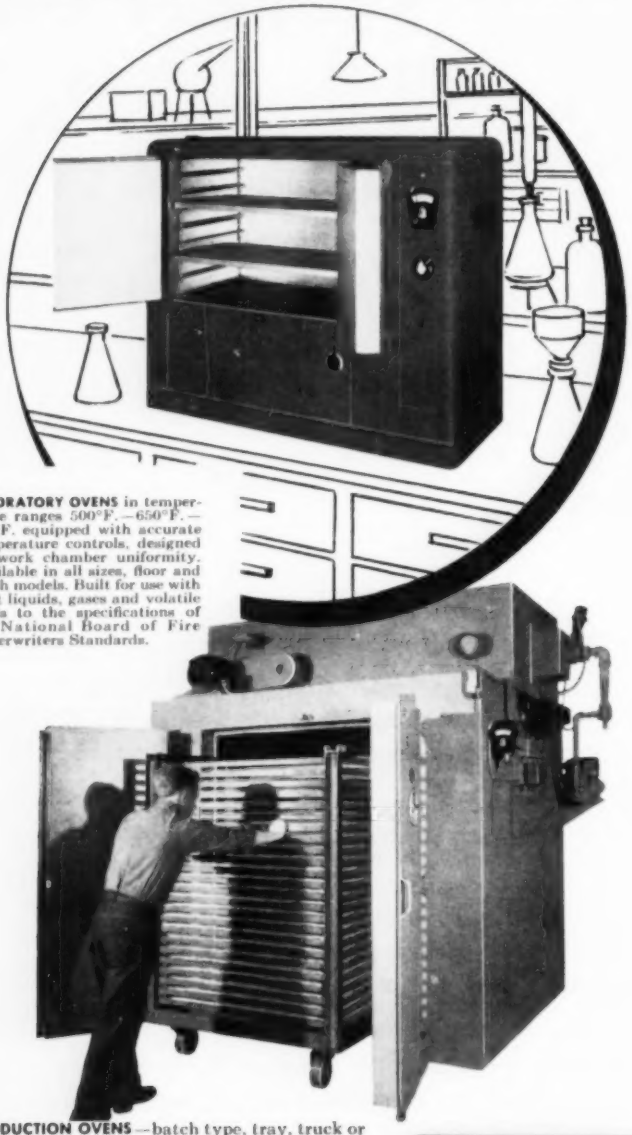

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Letters to the editor

from page 28

scale systems of similar basic nature utilizing the best experience available to us from the outside operations as well as experience within the Company in numerous smaller scale information handling systems.

In the Subcommittee Meeting it was suggested that the members would benefit by detailed explanation of the du Pont systems. To this end Eugene Wall of the Engineering Service Division, Engineering Department, du Pont, prepared a collection of papers and additional explanatory material relating to these systems and supplied each member of our subcommittee with copies. As the next step, we proposed that the subcommittee should meet in Wilmington for the purpose of viewing the du Pont systems in actual operation.

Our subcommittee so far has been made up of people entirely from industry, and it is believed that we should also include academic representation.

ROLLIN D. MORSE

Development Eng. Div.
E. I. du Pont de Nemours & Co., Inc.
Wilmington, Delaware

Another major polypropylene expansion is underway, this time at AviSun. Contract for a 100 million pound-per-year plant has been awarded to Bechtel. Site will probably be in Eastern United States.

Two chemocides, methyl and propyl esters of p-hydroxybenzoic acid have been allowed by the Food & Drug Administration for applications as food preservatives at 0.1 percent. They are made by Chem Puro Manufacturing (Century Chemicals).

Major expansions underway in polyethylene capacity at several firms call for large increases in production. Dow plans increase of 67 percent with facilities at its Texas Division, Freeport. Allied Chemical has selected Orange, Texas, as the site for its high density polyethylene plant. The new unit will adjoin an ethylene derivative plant operated by the company's Nitrogen Division. It will be used in making A-C polyethylene pipe compound. Dow is also completing a polyethylene film plant at Fresno, California. Film for building, flexible packaging and agricultural applications will be made.

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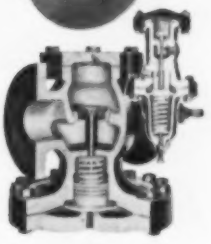

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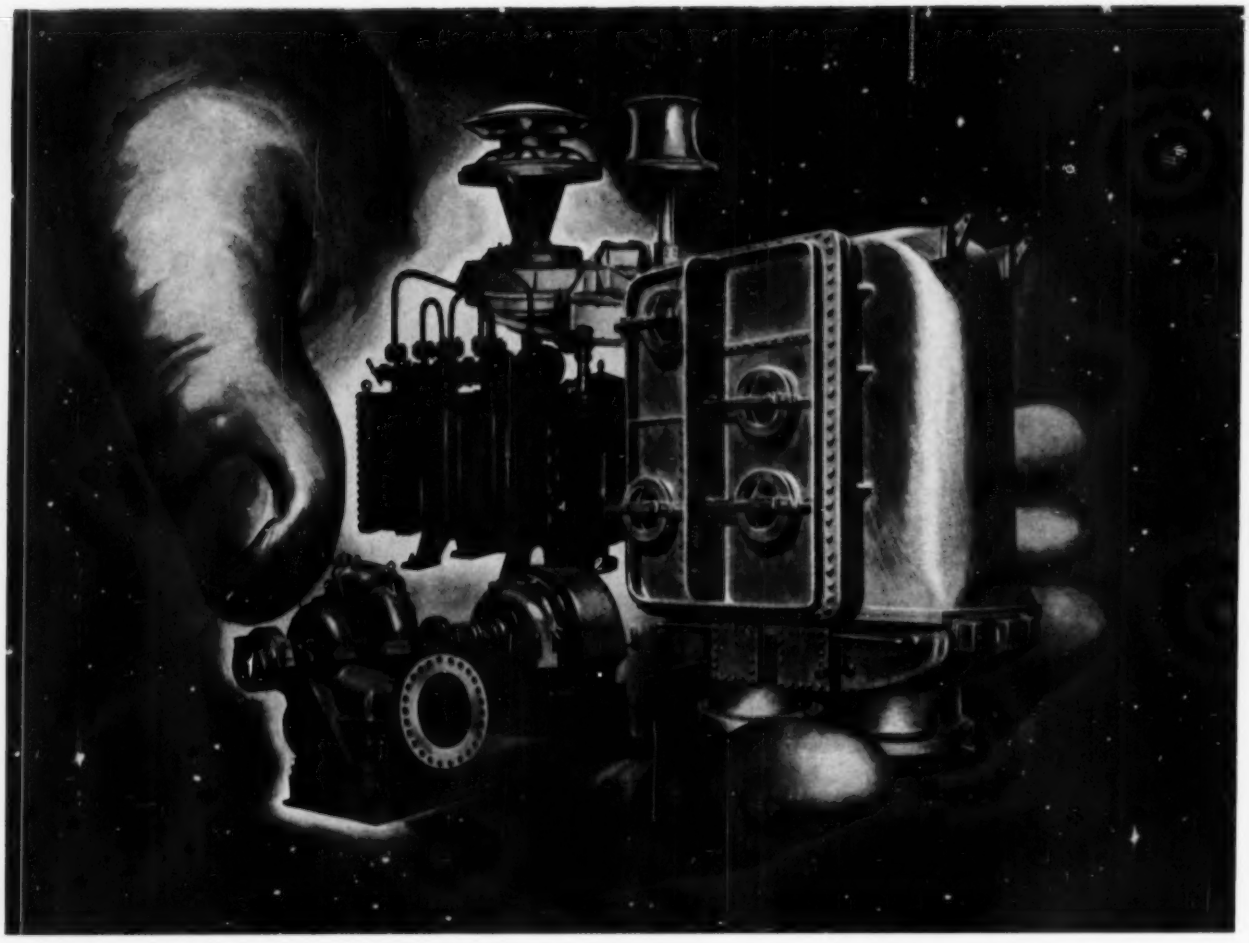

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Cool heads call for keeping posted on Ivan

THE LITERATURE IS SWAMPED these days with reports on Soviet strides in science and engineering. International technical symposia are highlighted by contingents of authors from Iron Curtain countries. Russian technical teams are found scattered around the world. And their all-important counterparts, the trade missions, are hard at it making deals wherever they can.

A trend? Yes. A continuing one? Definitely. One that can be ignored? No. One that must be taken seriously? Absolutely! One that should be taken at face value? Well, now, here's a point for discussion.

The in, the out, the in-between

There are two wide areas of opinion—with gray shading in between—when the subject of the Soviets comes up in technical discussions. One gets passionately concerned at their overtaking us to the extent that he is willing to scuttle basic tenets of our business and political systems. The other discounts their achievements — notwithstanding the Sputniks—and assumes that the Iron Curtain, in reverse, will keep our industry from being affected. It's easier to be objective in the in-between. How many fall in this area is hard to determine, for the intensity of the vocal outcries from either end of the spectrum is not in direct or inverse proportion to anything. An objective appraisal can be made, within reason.

The Russians prepare and present a lot of technical papers. No question here. In fact, at the July meeting of the International Congress on Catalysis more than 15 percent of the papers will emanate from Iron Curtain countries. Will they all be worthwhile? If past performance is any indicator, many of them will deal with ideas and technology long-since relegated to the archives in this country. This was the case at the World Petroleum Congress last year. *But* one out of five may be a real gem; one which is a true contribution. And therein lies the importance of keeping abreast of their developments. The percentage can change rapidly with the heavy emphasis being put upon research in Russia. One of our prominent industry scientists expressed concern over whether, in our preoccupation with applied research, we may not have to turn to some of their works in the years ahead for basic information. At any rate, from the aspect of keeping well-informed, a rational, continuing study of what's being done by them is in order.

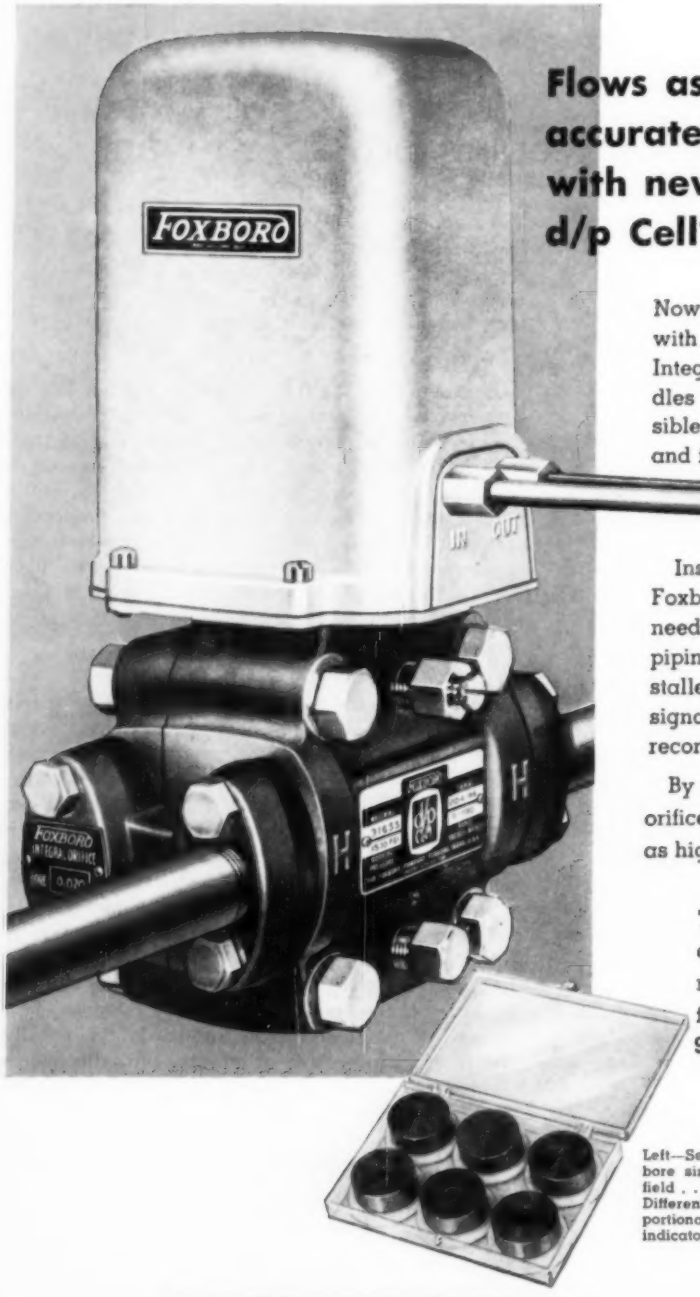
Writings galore

Contrary to some opinions, they do make it relatively easy to keep posted on their doings. Lawrence Ross of Georgia Tech says the Russians rank second among all nations in output of literature. The obvious reason why most goes unnoticed here is the translation problem. The reverse is not the case, for American trade and technical publications are thoroughly digested in their institutions. The object lesson; we can gain from what may be available in their papers and publications, but it requires the translation effort first.

An area of major importance to the chemical industry is the activity of the trade missions. True, many of the deals made are made for political purposes, irrespective of profits. But, this has its limits and sooner or later they'll have to measure up to the overall competitive situation. They are already making tiny inroads in the world market—one which is getting to be a rough-and-tumble place as more plants come on stream abroad. The Soviets, simply as "legitimate" vendors of chemicals, pose one big potential threat to the export market.

The trend indicates this threat will grow in actuality. From the objective center-of-the-road, it behooves the chemical industry to stay abreast of, preferably ahead of, the trend.

FOXBORO BREAKS "RANGE BARRIER" IN SMALL-FLOW TRANSMISSION



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opinion and comment

Tangible approach to the intangible

The intangible nature of industry problems such as the downtrend in engineering enrollment makes them fair game for armchair analysts—loaded with critiques, suggestions, and slogans. But, alas, in their tireless, albeit wellmeaning exposition, most of them, if not all, skirt the all important area of implementation.

We've seen and heard of this very serious trend innumerable times in recent months. The alarm has been sounded. And the analysts have generally come up with outstanding phrases: "We must reverse this trend . . . This is a victory for the Soviets . . . a body blow to America . . ." Outstanding phrases pour forth ad infinitum, but only a trickle is to be found on just what to do about it.

A solution

Thus, it was like a breath of fresh air to hear Dr. Ed Harrison, President of Georgia Tech., wade into the problem at the A.I.Ch.E. national meeting in Atlanta, and come up with a positive, hard-hitting solution. He chooses to go back to the source of the problem: the elementary and secondary classroom. The student must be exposed to scientific and engineering principles adequately and properly in these years says Dr. Harrison so he'll be willing and eager to tackle the rigors inherent with a technical education. But the burden isn't on the student alone. The teacher must know the *content* of the subjects. Having an educator's background per se is not enough. Rather the emphasis should be placed on the teacher's being familiar with his subjects. We can help in this by beating on the door of our local school board and press for the upgrading of their educational offerings.

The board members might even crack the barrier of education restrictions to permit available engineering talent to teach science or mathematics in communities where there are no qualified teachers. Competent engineers in residence without teacher's certificates and/or an educator's training are normally excluded from teaching in public schools. This won't be easily accomplished says Dr. Harrison. This means we may have to knock several times.

Finally, says he, we should work for the obliteration of the "insidious" practice of across-the-board salary increases and a seniority system which has kept some ambitious and capable teachers out of the public schools. Again, it means a bit more legwork and door knocking on our part. The effort on the local level can have a positive effect in reversing the trend. But it requires more than mere acquiescence—it requires time, it requires work, and this by all of us, individually and collectively.

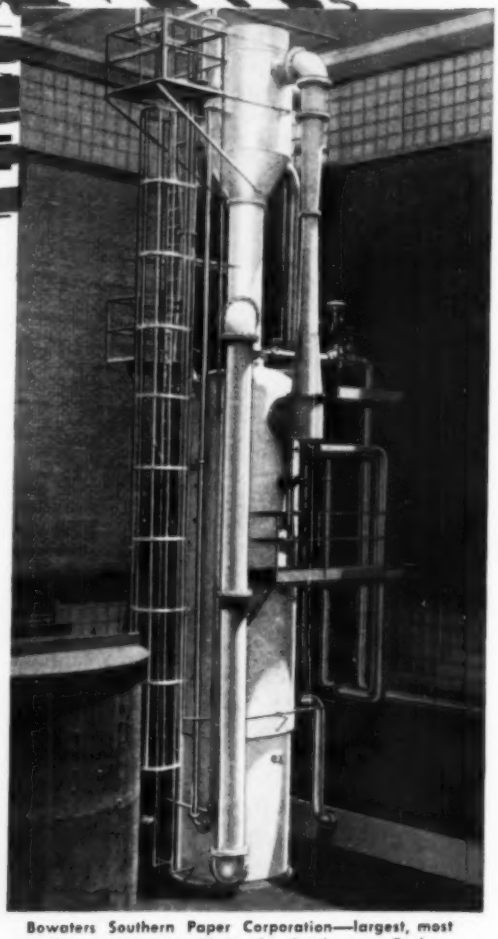
Dr. Harrison's ideas, since they upset some "semi-traditional" aspects of the educational field, may not be universally popular. Since he asks for action on the part of us, those prone to laziness may be willing to let someone else carry the ball. But to borrow a phrase from our verbally maligned analysts "It's not someone else's problem. It's your problem and my problem, and the responsibility lies heaviest on those of us in engineering. Now is the time to do something about it!"

Ed Harrison has shown a way how.

L. R.

"Water, water everywhere..."

...and not a drop under 95°!



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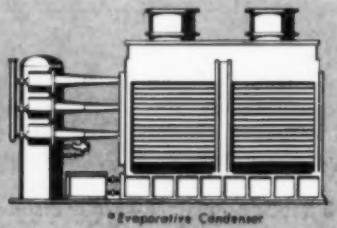

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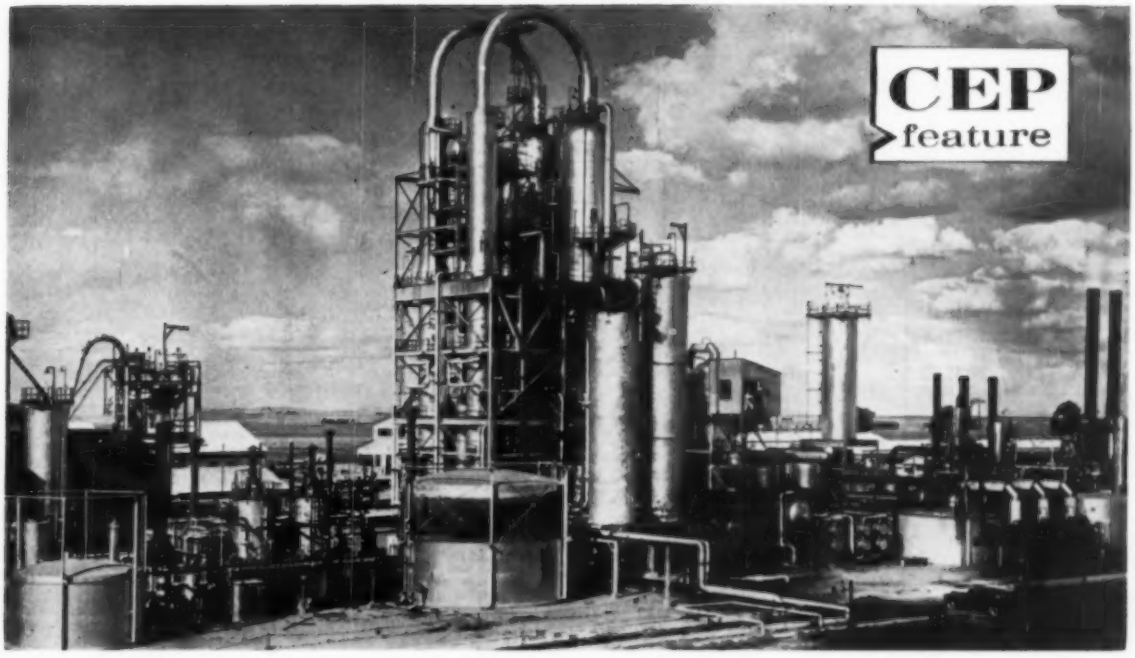


Kellogg unit for synthesis of motor gasoline from coal gasification products.

L. W. Garrett, Jr.

Gasoline from coal via the Synthol process

SASOL plant in South Africa solves gasoline shortage by producing synthetic fuel through gasification products of sub-bituminous coal.

Gasoline production from coal via the Synthol process has been realized on a commerical scale at the South African Coal, Oil & Gas Corporation (SASOL) plant in the Union of South Africa. The basic plant has been built to process a sub-bituminous coal to make synthesis gas for the production of motor gasoline as well as a variety of oxygenated chemicals, a diesel oil, and several wax products. Facilities were also included to produce by-product phenol and ammonium sulfate from the gas liquor product of the coal gasification plant. The purpose of this article is to discuss those portions of the plant which are involved in the production of the primary motor gasoline and chemical fractions. It should be helpful, however, to describe first the over-all process scheme as shown in Figure 1.

Coal is delivered from the nearby mine by means of conveyor belts to the coal gasification and power plant units. The coal is gasified under pressure in Lurgi reactors using superheated steam and essentially pure oxygen. The gas liquor stream from the gasification plant yields phenol and ammonium sulfate as by-products. Tar and light oils are recovered from the hydrocarbon condensate from the coal gasification unit. The raw gas is then processed for the removal of CO_2, H_2S, and organic sulfur and is fed to the two synthesis plants. The Arge (German) synthesis is utilized to produce primarily diesel oil and wax fractions, whereas the Kellogg synthesis produces primarily motor gasoline. A catalytic gas reformer is employed to prepare feed for the Kellogg synthesis since the methane content of the purified coal gas is too high to be economically processed. Also, certain tail gases must be reformed for recycling to the Kellogg

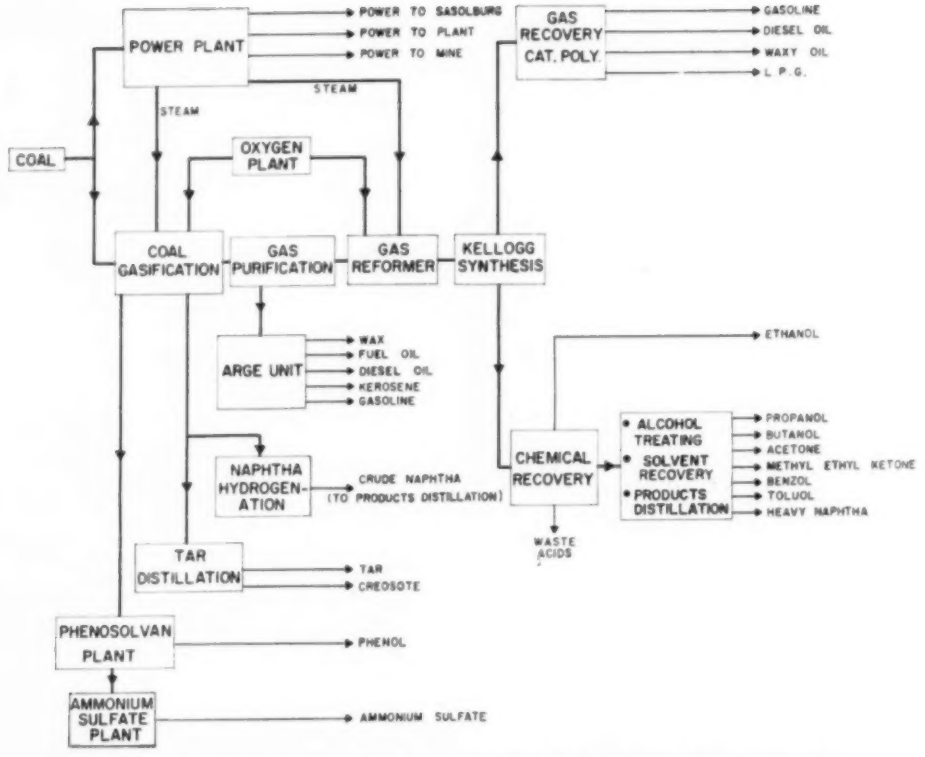


Figure 1. The over-all process flow diagram for the SASOL plant in South Africa.

synthesis unit. The hydrocarbon liquid and vapor streams from the synthesis are sent to a gas recovery and catalytic polymerization plant, while the aqueous stream containing oxygenated chemicals is processed to produce a variety of pure products. No particular attempt is made to recover chemicals from the oil phases coming from the Kellogg synthesis plant.

Feed gas preparation

The above shows the rather complex over-all plant scheme. The first step in this scheme—the preparation of synthesis gas—is a vital one, and contributes about three quarters of the investment cost of the over-all plant. The Lurgi pressure gasification process has been used for preparation of the raw synthesis gas. This plant gasifies 3050 tons/day of coal (1920 tons/day of moisture and ash-free coal) to produce 162,000,000 std. cu. ft./day of raw gas. The gasifiers operate at about 380 lb./sq.in. gauge pressure. The gas is purified in a Rectisol Unit (Lurgi) by scrubbing with cold methanol to remove H_2S, organic sulfur, and CO_2. In this fashion a pure synthesis gas is prepared having the following composition:

Gas	Mol %
N_2	1.4
H_2	56.1
CO	26.7
CO_2	1.5
CH_4	14.3
	100.0

The coal required for steam and power generation for the entire plant is 2350 tons/day for a total coal consumption of 5400 tons/day.

The purified gas is blended with tail gases from the Kellogg synthesis and the Arge synthesis, and is then reformed with high purity oxygen and steam over a nickel catalyst. This step is carried out at 300-350 lb./sq. in. gauge pressure and 1600-2200°F. The reforming reduces the hydrocarbon content and also provides control of the H_2/CO ratio in the gas to the synthol reactors. The fresh feed to

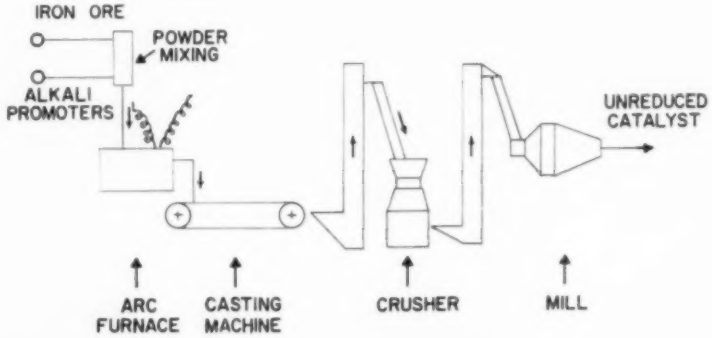


Figure 2. Preparation of iron catalyst for the Synthol reaction.

the synthesis unit then has the following composition:

Gas	Mol %
N_2	3.9
H_2	61.8
CO	22.4
CO_2	7.2
CH_4	4.7
	100.0

The design feed rate is about 145,000,000 std. cu. ft./day.

Synthesis

The synthesis is carried out over an iron catalyst in a single stage powdered catalyst reaction system. The basic synthesis reaction is the hydrogenation of CO to yield hydrocarbons and water. Side reactions also produce oxygenated compounds. The synthol catalyst and the synthesis reactor are the heart of the process. The synthesis catalyst for this plant is prepared by fusing a magnetite ore with alkali in an electric arc furnace as shown in Figure 2. Alkali and ore are precisely blended and fed to the arc furnace. The furnace is tapped several times an hour while being fed continuously. The molten material is cast into small pigs to promote rapid cooling and then crushed and milled to yield a powder in the 40 micron average particle size range. This material must be reduced to essentially pure iron before it is used as a catalyst. This reduction is done in a fluidized bed with essentially pure hydrogen at about 250 lb./sq.in. gauge pressure. The reduction temperature is in the range of 700-750°F, and the process is carried out batchwise. A steam-iron plant is used for the production of the pure hydrogen required for this reduction. Close control

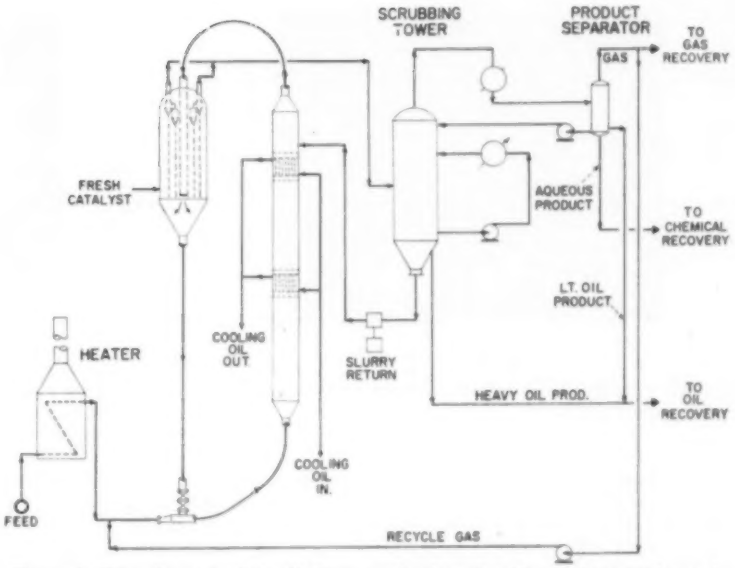
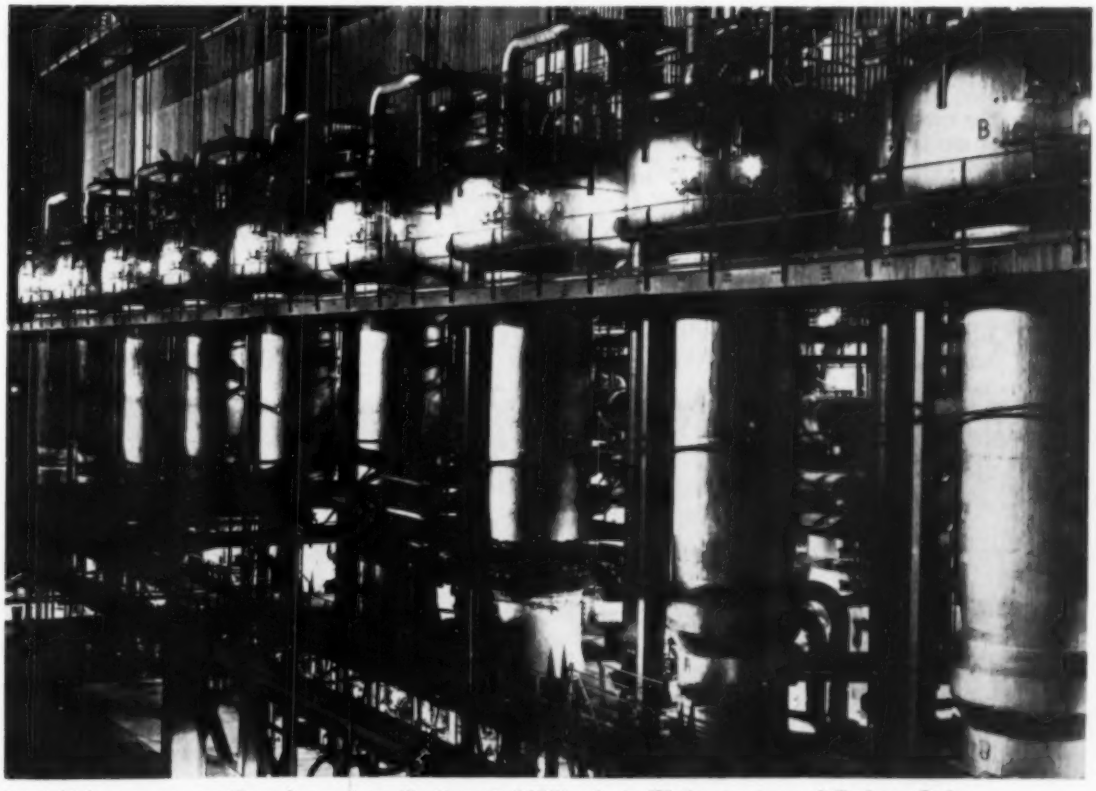


Figure 3. Flow diagram of the Kellogg synthesis unit with auxiliary equipment.



Lurgi high pressure gasifiers for coal gasification at SASOL plant. (Photo courtesy of Foxboro Co.)

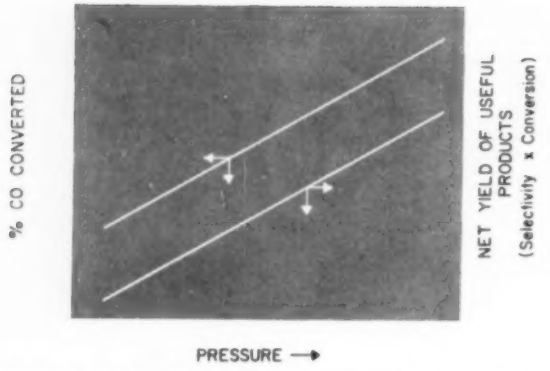


Figure 4. Qualitative effect of pressure on CO conversion and product yield.

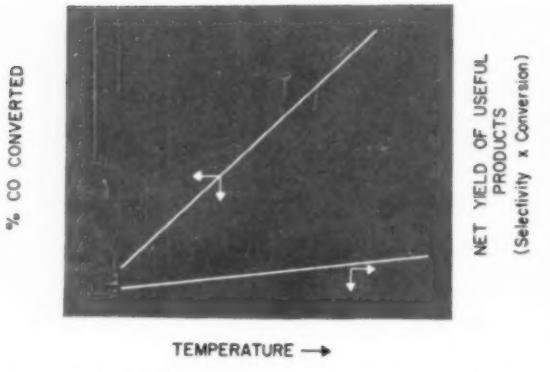


Figure 5. Qualitative effect of temperature on CO conversion and product yield.

of all phases of the catalyst manufacturing process has been found to be essential in producing a proper catalyst.

The synthesis reaction system is shown in Figure 3. The synthesis gas coming from the reforming section is preheated and mixed with recycle gas before entering the reactor. Catalyst and gas mix in the transfer line and flow with a velocity of 25-35 ft./sec. to the reaction zone. The reactor operates with a gas velocity of 4-7 ft./sec. with the catalyst-gas mixture moving through the reactor-cooler sections and into the settling zone. Here most of the catalyst disengages and recirculates down through the standpipe and slide valves. Cyclones are installed in the settling zone to remove most of the entrained fines. Circulating oil around the reactor cooler tubes aids in controlling reactor temperatures. Close control of the exothermic synthesis reaction is essential to optimum product yield.

Reactor effluent gas is quenched in a scrubbing tower where the remaining catalyst dust is removed. This fine catalyst is returned to the reaction zone in the form of a heavy oil slurry. This scheme permits operation without catalyst loss. A heavy oil product is taken off the bottom of this tower and the other synthesis products go overhead in the vapor phase. These products are cooled and separated into a gas phase and two liquid phases—water and oil. Gas is also taken off the separator and returned to the reaction zone to increase CO conversion, aid in catalyst circulation, and aid in controlling reaction temperature. The synthol reactor system thus has three ways in which the exothermic reaction may be controlled:

1. Rate of catalyst circulation through the slide valve.
2. Heat removal through the cooling oil circuit.
3. Amount of recycle gas returned to the reactor.

The raw products from the synthesis require certain treatment and then final purification to make the specification products. From the gas phase valuable hydrocarbon and chemical products are scrubbed out and recovered. The oil phase is treated catalytically to remove dissolved oxygenates and then distilled into gasoline and fuel oil fractions. The water phase is first distilled to remove organic acids which are discarded in this case. The remaining concentrated chemical solution is then further fractionated to produce chemical products. The products from these recovery operations are shown in Table 1. Heavy alcohols through pentanol are also being recovered now as specification products.

Synthesis reaction variables

The Fischer-Tropsch synthesis reactions present many problems in de-

Table 1. Products recovered from Kellogg Synthesis.

Products	Barrels/Day
L P G	24
Gasoline (86-90 CFRR clear)	3260
Diesel oil	142
Waxy oil	46
Methanol	14.5
Ethanol (crude)	12.0
Ethanol (pure, anhydrous)	302.0
Methyl ethyl ketone	21.8
Acetone (pure)	15.8

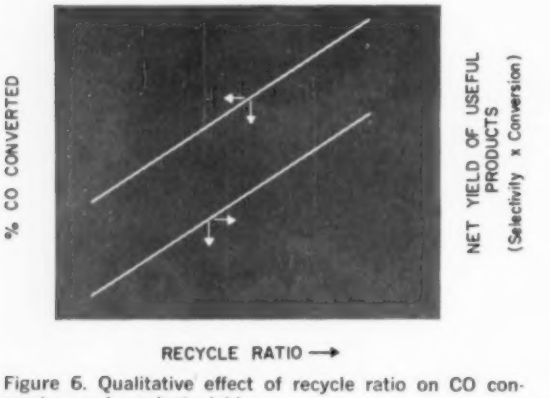


Figure 6. Qualitative effect of recycle ratio on CO conversion and product yield.

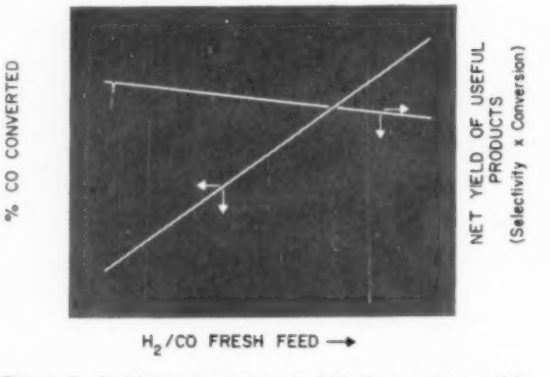


Figure 7. Qualitative effect of H_2/CO feed ratio on CO conversion and product yield.

Luther W. Garrett, Jr. is chief development engineer at M. W. Kellogg in New York City. He received his chemical engineering degree from the University of Texas, and joined Kellogg in 1947. Since then, he has been employed by the company in various phases of process, design and operating activities. Garrett was first process engineer, and later project manager on the South African Coal, Oil & Gas Corporation (SASOL) plant in the Union of South Africa.

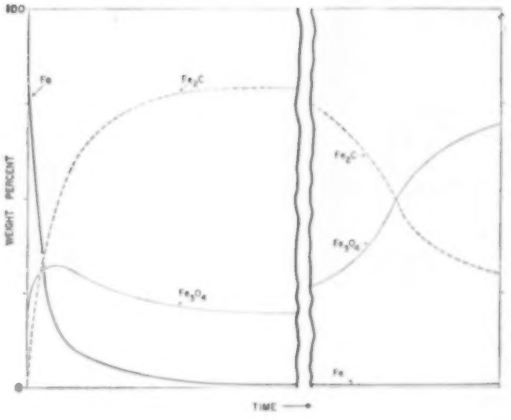


Figure 9. History of Synthol catalyst during process operation. The iron catalyst is initially conditioned at reduced pressure and high H_2/CO ratio to form an iron carbide and oxide phase. Following this period, the standard operating conditions are set and the catalyst composition changes to increase the oxide phase as shown at right.

sign and operation due to their complex nature. In a commercial design such as SASOL, control of certain of these variables over a fairly wide range should be incorporated in the plant design. These are: pressure, temperature, recycle ratio, fresh feed composition, catalyst composition.

1. Pressure. Figure 4 shows that increasing the reaction pressure within the range 250-350 lb./sq. in. gauge used at SASOL yields a marked increase in percent CO conversion and also improves catalyst selectivity toward liquid products.

2. Temperature. Within this range of pressure conditions, Figure 5 shows that increasing reaction temperature over the range of 590-650°F used at SASOL, has a marked effect on percent CO conversion but gives poorer selectivity to liquid products; it therefore yields only slight improvement in net products.

3. Recycle Ratio. Under these pressure and temperature conditions, Figure 6 shows that the recycle ratio improves percent CO conversion and net product yield in about the same proportion in the range of recycle ratios of 2/1 to 2.5/1.

4. Fresh Feed Composition. Figure 7 shows that increasing H_2/CO ratio in the feed under any of the above conditions increases percent CO conversion. In a given plant, however, this results in less net carbon in the feed and therefore slightly decreases net production. This is due to the fact that the higher hydrogen content of the feed gas is obtained only through the formation of CO_2 which must be wasted. The range of H_2/CO ratios employed in synthesis at SASOL is 2.8/1-3.3/1.

Any change of these variables, however, may also have an effect on the life of the synthesis catalyst. Figure 8 shows that increasing pressures and recycle ratio in the ranges above have negligible effect, while increasing temperature shortens catalyst life and increasing H_2/CO ratio lengthens catalyst life. All of these effects must be therefore balanced out to give maximum over-all plant efficiency.

The synthesis catalyst undergoes considerable change in composition during its life. Figure 9 shows this pattern from the initial reaction time. During the initial reaction stage the catalyst is conditioned at reduced reactor pressure using a feed gas with somewhat higher H_2/CO ratio than normal. During this period the catalyst composition changes quite rapidly: the α-Fe content drops off rapidly as the iron carbide and iron oxide phases form. The Fe_2C rises sharply to a peak as the Fe_3O_4 rises slightly at first and then falls off. Following this period the pressure is raised to normal operating conditions and the Fe_2C then falls off as the Fe_3O_4 rises. The feed gas composition is adjusted to the normal condition at this time and the catalyst composition continues to change until the carbide and oxide proportion has reversed itself. Beyond this point it has been found that the catalyst composition changes only slightly with free carbon and wax beginning to build up on the catalyst in this latter period. The catalyst activity declines sharply after the conditioning period, and then very gradually thereafter. Therefore the rate of catalyst replacement, either continuously or intermittently, determines the so-called "equilibrium level" of the plant's production.

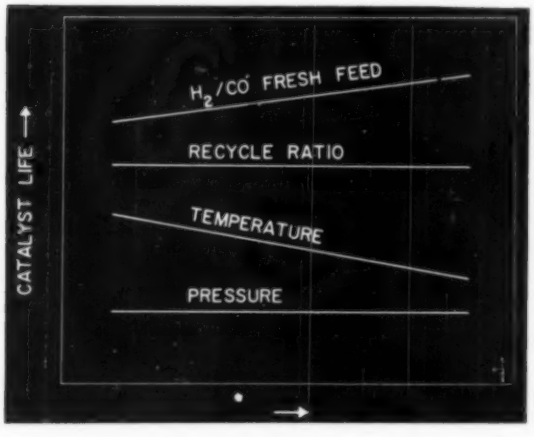


Figure 8. The effect of changing process variables on the life of the synthesis catalyst shows that increased H_2/CO ratio lengthens catalyst lifetime while increased temperature reduces lifetime. These effects must be balanced with plant operation to give maximum over-all plant efficiency.

J. H. Field, H. E. Benson, R. B. Anderson

Synthetic liquid fuels by Fischer-Tropsch process

The first synthetic fuel plant based on coal in this country will be able to take full economic advantage of the byproduct chemicals.

The production of liquid fuels from coal by the Fischer-Tropsch synthesis can be divided into four major steps: coal gasification, gas purification, synthesis, and product treating and refining. Although interest in synthetic fuels processes has waned during the past decade because of unfavorable economics and new discoveries of oil, particularly in Canada and the Middle East, an appreciable amount of research has been continued and some commercial development has resulted. Catalyst research and bench-scale and pilot-plant studies of synthetic fuels processes have been continued at the Bureau of Mines.

This article summarizes recent commercial developments and the current status of the coal gasification, gas purification, and catalytic synthesis steps.

Coal gasification

Gasification of coal, Table 1, must be accomplished at elevated pressure to be economically attractive for a synthetic fuels industry. This avoids the necessity for compressing the synthesis gas to the required process pressure of 300-400 lb./sq.in. The only coal gasification process employed commercially at elevated pressures thus far is the Lurgi fixed-bed system, and this is limited to a relatively noncaking feed of selected size.

Lurgi gasification is being employed successfully at a pressure of 450 lb./sq.in. in the South African synthetic fuels plant, Sasol *(1)*. Lurgi gasifiers are operated in Australia and similar units are being installed in Great Britain *(2,3)*.

In South Africa, a market for CH_4 as a fuel gas has not been developed. The CH_4 left in the synthesis gas after conversion of the H_2 and CO to liquid fuels is reformed to additional H_2+CO for further utilization in the Sasol plant by partial oxidation under pressure with additional oxygen.

In the United States (by the time a synthetic liquid fuels industry is started our supplies of natural gas probably will be more nearly depleted) catalytic conversion of part of the synthesis gas and of the residual H_2 and CO in the tail gas to additional CH_4 would be economically attractive. This feature—making controlled quantities of both synthetic liquids and gaseous hydrocarbons—would be helpful in compensating for seasonal fluctuations in the demand for both gasoline and natural gas.

The Texaco partial oxidation process *(4)*, although now being used on a large scale with natural gas and oil, has not yet been applied commercially to coal. However, development of this process with powdered coal was studied recently in a large-scale installation at the Olin Mathieson ammonia plant at Morgantown, W. Va. *(5)*. A slurry of pulverized coal and water is pumped to a preheating furnace, and the resulting steam-coal mixture is fed to the gasifier with oxygen. The results have not been published.

Pulverized coal is being gasified at atmospheric pressure commercially by the Koppers-Totzek process in Finland and Japan. A horizontal gasifier is used with the reactants injected at opposite ends to obtain turbulence. Detailed operation of the plant at Oulu, Finland, has been described *(6)*.

Considerable pilot plant development of coal gasification processes is continuing in Europe and in the United States. In Great Britain the Gas Council has studied modifications of the Lurgi process to increase the Btu value of the gas and to operate at slagging conditions *(7)*. Gasification of pulverized coal with air in a slagging cyclone generator is being investigated at the Fuels Research Station, Greenwich, and a study of gasification of powdered coal at slagging temperatures by injection into a bed of large coke has been begun *(8)*. The British Coal Utilization Research Association at Leatherhead, Surrey, also is active in research in coal gasification. A 2-ft. diam. cyclone unit is being operated to gasify pulverized coal, and an experimental Lurgi gasifier to operate at slagging conditions is being built in cooperation with Costain John Brown, Ltd. *(9)*.

Two other coal gasification schemes are being developed in Germany. The Flesch-Demag gasifier at Ludwigshafen uses two adjacent interconnected generators *(10)*. Both fixed-bed and fluidized-bed operation are used in a cyclic arrangement. Granules of coal up to about 1/2-in. are used. Steam and oxygen are fed downward through a fixed bed in one generator whereas the bed in the other gener-

ator is fluidized by steam flowing upward. The turbulence in the fluidized bed loosens the slag, which drops with the heavy ash to the bottom of the bed for removal. Coal is added during the fluidizing cycle. No results of operation at elevated pressure have been reported, but the results at atmospheric pressure have been favorable.

Another German system, the slag bath generator, is being developed by Rummel at Wesselring *(11)*. A pool of slag is maintained at the bottom of the generator into which pulverized coal is blown along with steam and oxygen. A lower usage of oxygen is claimed for this system than for comparable gasifiers—248 cu. ft./1000 cu.ft. H_2+CO, compared with 300-350 cu.ft. for other pulverized coal gasification systems.

In the United States a pilot plant for gasifying pulverized coal with oxygen and steam at elevated pressure is being operated by the Bureau of Mines at Morgantown, W. Va. *(12, 13)*. The Bureau also is constructing a slagging Lurgi-type unit at Grand Forks, N. D.

Gas purification

Carbon dioxide and hydrogen sulfide, together with a small amount of organic sulfur compounds such as carbonyl sulfide, are the principal impurities in synthesis gas. Other impurities such as dust, tar, and liquid hydrocarbons formed in varying amounts in different gasification processes must be removed before the gas is purified further.

The removal of CO_2 and H_2S from synthesis gas, Table 2, and other industrial gases has been achieved in this country chiefly with mono- or diethanolamine, but in Europe water scrubbing is usually preferred, undoubtedly because of the large volume of steam required for regenerating amine solutions, and its high cost.

The Sasol plant successfully employs the Rectisol process for gas purification, the first large-scale application of this process *(1)*.

The hot potassium carbonate system *(14)* developed by the Bureau of Mines for removal of CO_2 and H_2S has come into commercial use during the past few years. About 14 plants are in operation or under construction. In addition to CO_2 and H_2S, organic sulfur in the form of carbonyl sulfide is completely removed as it is hydrolyzed to CO_2 and H_2S by the hot, concentrated (25-35%) solution of K_2CO_3. By proper staging, the concentration of H_2S in the gas can be lowered to the tolerance required for the Fischer-Tropsch synthesis. Installation costs are lower than for amine systems because of the elimination of heat exchangers for sensible heating of the solution and the reduction of reboiler requirements. Steam consumption is only about 1/3-1/2 that of amine systems. This process is being used to purify ammonia synthesis gas, refinery hydrogen, industrial heating gas, and natural gas.

Synthesis

Because much heat is evolved in the synthesis reaction (7000 Btu/lb. product), heat must be removed to control the catalyst temperature within desirable limits. Several reactor systems have been devised for this purpose. Both indirect heat transfer from the catalyst through metal walls to a boiling liquid and direct heat transfer to a circulating gas or liquid in contact with the catalyst have been employed. The most common types of reactor systems are illustrated schematically in Figure 1 *(15)*.

Fixed-bed reactors (1-a) with indirect heat removal were used commercially by the Germans up to the end of World War II. Because of their limited throughput, an improved design has been developed (1-b) resulting in a 20-fold increase in capacity over the early fixed-bed units *(16)*.

Direct removal of the heat of reaction from the catalyst surface by cooling oil is employed in the slurry (1-c) *(17)* and oil circulation (1-d) systems *(18)*, and by a circulated tail gas in the hot gas recycle (1-e). Although these systems afford excellent control of temperature, none has been used commercially. The fixed, fluidized bed (1-f) and a modification using an entrained fluidized bed are operated in a manner similar to petroleum cracking units. Both of these systems produce principally gasoline and have been used commercially.

The present status of the various reactor systems and a comparison of their operation are given in Table 3. The early fixed-bed reactors are obsolete, but are still being used in a 50,000 ton/yr. plant at the Chemische Werke Bergkamen, A.G. at Essen *(19)* and at Krupp Kohlechemie G.m.b.H. at Wanne-Eickel *(20)* prin-

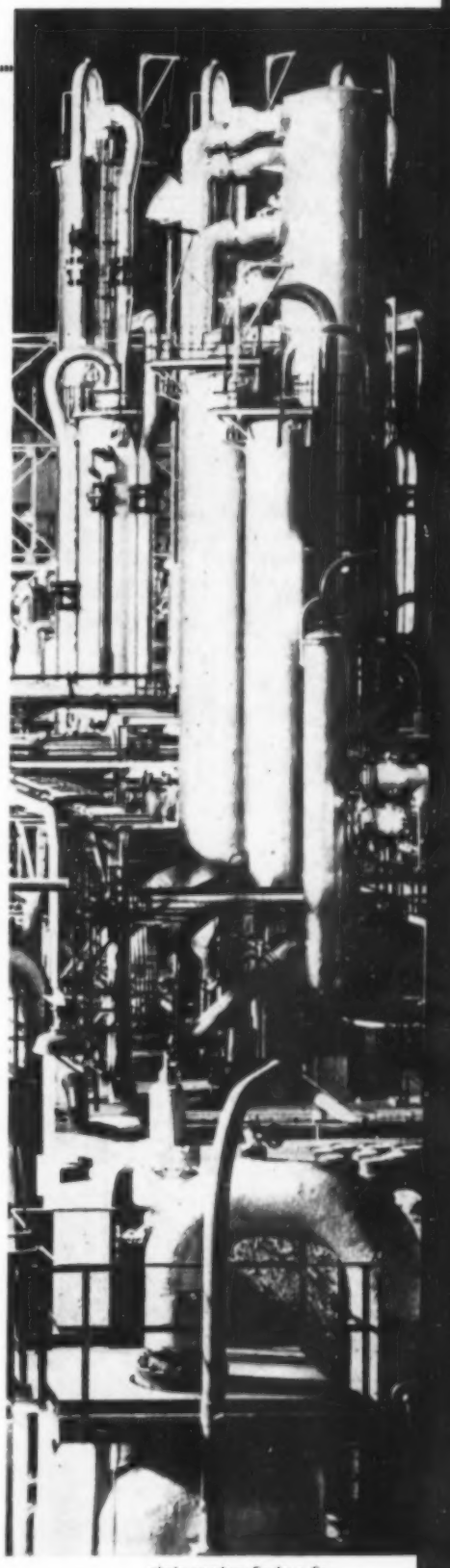
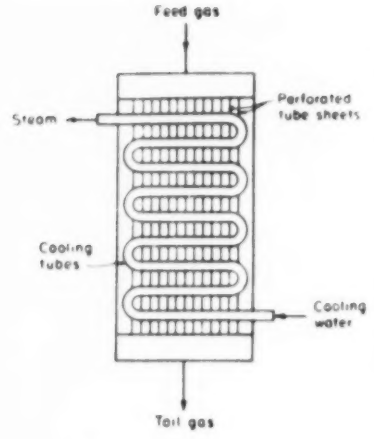
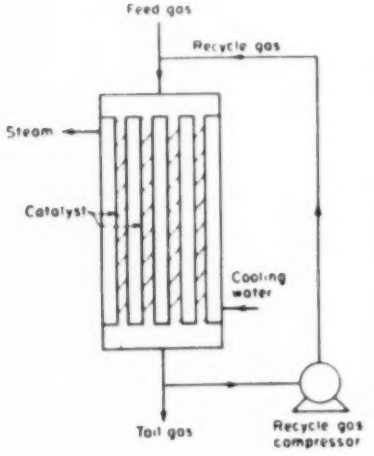


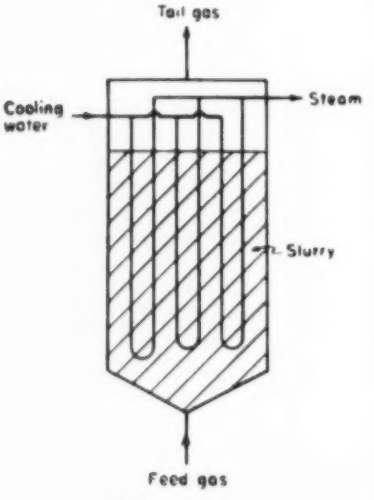
photo courtesy Foxboro Co.



(a) ATMOSPHERIC PRESSURE FIXED-BED



(b) LURGI-RUHRCHEMIE MODERN FIXED-BED



(c) SLURRY

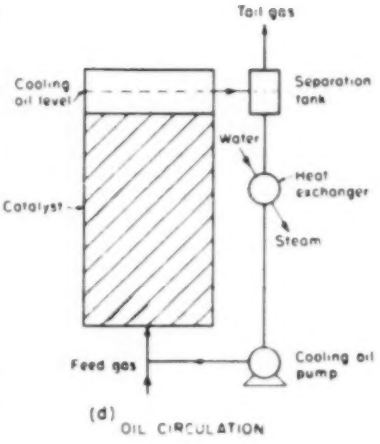
cipally for the production of waxes and high-boiling aliphatic alcohols. Recent improvements in the fixed-bed system have been made jointly by Ruhrchemie and Lurgi that permit increased production. Improved heat transfer through the catalyst has been achieved by increasing the linear velocity of the gas to about 0.4 ft./sec. Use of larger-sized catalyst than in the early units has also been instituted. This system is being used in the first stage of synthesis at Sasol.

The fluidized bed reactors were developed in the United States to increase the capacity of Fischer-Tropsch reactors, to reduce capital costs, and to allow operation at the high temperatures at which the principal product is gasoline. Both the fixed and entrained systems have been operated commercially. While the heat transfer coefficient through fluidized beds is quite high, the heat evolution is so great that an appreciable temperature gradient exists between the catalyst surface and the steam in the bayonet coolers.

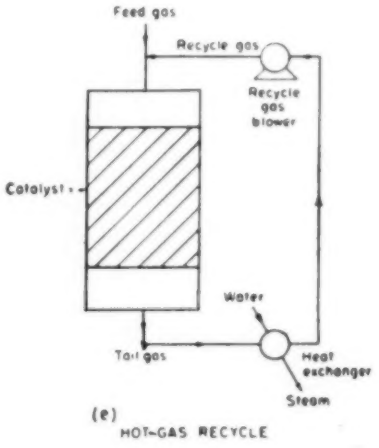
The remaining processes, listed in Table 3, have been investigated only on a pilot-plant scale. In these processes employing direct cooling, the temperature gradient between the catalyst surface and cooling medium is very small because the large surface area of the catalyst is involved in the heat transfer. The oil circulation process has been studied at the Bureau of Mines for several years *(18)*. Steel lathe turnings oxidized with steam to form an outer layer of iron oxide have proven to be a durable and active catalyst. Steady operation for about six months has been achieved at temperatures to 280°C. At higher temperatures the rate of catalyst disintegration is accelerated.

Less progress has been made in the development of the slurry process which is being investigated by the Bureau of Mines and by the British Fuels Board. Difficulty has been encountered in maintaining suspension of the pulverized catalyst in the cooling oil. Catalyst settles to the bottom or deposits on the walls of the reactor, causing rapid loss of gas conversion. The reactor in the British pilot plant at the Fuel Research Station is about 10-in. diam. and 16-ft. high; the slurry volume is about 5 cu.ft. *(8)*.

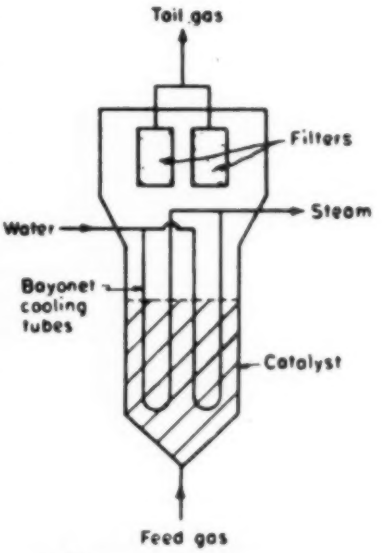
Development of the lathe turnings catalyst has made the hot-gas recycle



(d) OIL CIRCULATION



(e) HOT-GAS RECYCLE



(f) FIXED, FLUIDIZED-BED

← →

Figure 1. The most common types of synthesis reactor systems.

Table 1. Coal gasification process.

Process	Lurgi	Entrained		Winkler	Flesch Demag
Type of operation	Fixed-bed, non-slagging	Vertical or cyclone gasifier, slagging	Koppers horizontal gasifier, slagging	Fluidized, non-slagging	Cyclic, fixed-bed gasification
Status	Commercial	Mainly pilot plant	Commercial	Commercial	Large pilot plant
Capacity, tons coal gasified/hr.	15-20	0.2-4	5	45	4
Pressure	Elevated	Elevated	Atmospheric	Elevated	Atmospheric
Oxygen consumption, cu. ft./1000 cu. ft. $H_2 + CO$	230	300-350	300-350	300-350	250
Plant location or research groups	Germany, Czechoslovakia So. Africa Australia, Pakistan	Texas Co. I.G.T. BuMines Fuels Res. Sta. B.C.U.R.A. Ruhrgas, Ger.	Finland Japan	Leuna, Ger. Zeitz, Ger.	BASF, Ger.

system competitive with the other systems. Because this catalyst can be packed with a void volume of 85-95%, the pressure drop through the bed is low even at the high recycle ratios of 30-60:1 necessary for proper removal of heat. A pilot plant for the hot-gas recycle system is being operated at the Bureau of Mines. It has been operated at high temperatures for high gasoline production, and at low temperatures for higher boiling products or oxygenated chemicals.

Amoco Chemicals Corporation. In September 1957, the Amoco Chemicals Corporation announced the shutdown of its Brownsville synthetic oil plant *(21)*. In this plant partial oxidation of natural gas under pressure with oxygen of 95% purity was used to prepare synthesis gas. Major modifications after 1957, when Amoco assumed ownership, had consisted of the installation of a second gas generation unit, revamping of the oxygen plant to bring production up to design, and changes to the synthesis section.

The most difficult problem was encountered in the synthesis section. Originally the porous metal "bayonet" filters for separating the fine catalyst from the reactor tail gas were of Type 316 stainless steel. Reaction with the CO of the synthesis gas caused carburization and embrittlement. Replacement with carbon steel and glass wool filters greatly improved operations. More efficient cyclones were used with better results.

Difficulties encountered during the operations were catalyst deposition on the reactor internals, erosion of the internals, presence of hot spots in the bed, and high catalyst disintegration. Because the fine-mesh catalyst used in the fluidized reactors had a large surface area, the reaction rate was high and the release of heat per unit volume of the catalyst bed probably exceeded the capacity of the heat removal system. Carbon deposition and catalyst disintegration are accelerated under these conditions. Although progress had been made toward solving the operating problems, the company reported that the necessary additional modifications would have been too expensive.

In December 1958, the Union Carbide Corp. purchased the Brownsville facilities, not for any Fischer-Tropsch activities, but to produce petrochemicals *(22)*.

Conclusions

Because the days of cheap natural gas in the country are over, future synthetic fuel plants must be based on coal. The *first* plant will be able to take full economic advantage of the byproduct chemicals, but subsequent ones must necessarily direct their production to liquid and gaseous fuels. The use of a nitrided catalyst with which 40% by weight of the gaseous and liquid products are chemicals, compared to 5-20% with reduced and carbided catalysts, offers an inducement for the first plants built *(23)*. Moreover, with nitrided catalysts 80-90% of these chemicals are alcohols, whereas with reduced catalysts the alcohols make up only about half the chemicals and are more difficult to recover.

It is debatable whether it is preferable to operate the synthesis at high or low temperature. At the higher temperature, 280-320°C, higher gas conversions or throughputs are possible, higher pressure steam can be recovered from the synthesis, more C_1-C_2 gas is made, gasoline yields are higher, octane rating is higher (90-95 CFR), and heavy oil and wax yields are low. On the other hand, at low operation temperatures low yields of C_1-C_2 gases, low yields of gasoline with low octane ratings (60-70 CFR), and high yields of heavy oil and waxes are obtained. The products from the Arge and Kellogg synthesis units of the Sasol plant are typical of low and high temperature operation, respectively. The high temperature processes are advantageous in producing larger yields of gasoline

Table 2. Purification processes applicable to synthetic fuels.

Process	Impurities Removed	Basis	Operating characteristics
Water	CO_2, H_2S, part of organic sulfur	Solubility	Elevated pressure, 3-5% loss of synthesis gas by solubility
Rectisol	CO_2, all sulfur compounds	Solubility in methanol at low temperatures	Elevated pressure and refrigeration to about −70°F., does complete purification
Ethanolamines	CO_2 and H_2S	Chemical reaction	Elevated pressure desirable but can operate at atmospheric pressure
Hot carbonate	CO_2, H_2S, COS	Chemical reaction for CO_2 and H_2S. Hydrolysis of COS	Elevated pressure; operate at about 200°-250° F.
Iron oxide boxes	H_2S	Chemical reaction with Fe_2O_3	Used for final H_2S purification
Activated charcoal	All sulfur compounds	Adsorption	Used for final H_2S and organic sulfur removal

Table 3. Fischer-Tropsch reactors.

Type	Stage of development	Status	Hourly space velocity	Temp., °C.	Press. Atm.	Estimated heat transfer coefficient Btu/(hr.)(sq. ft.)(°F)	Calculated avg. catalyst temperature gradient, °F.	Catalyst	Principal products
Early fixed bed	Commercial scale, but obsolete	Two plants still in use for chemicals in West Germany	100	to 270	1-7	6	13.5	Precipitated cobalt or iron	Oxygenated chemicals and heavier hydrocarbons
Modern fixed-bed	Commercial scale	In use at Sasol	500	to 270	25-30	30	27	Precipitated iron	40% of liquids as gasoline; 60% heavier hydrocarbons
Fixed, fluidized-bed	Ditto	Used at Amoco Chemicals; now inactive	500	300-340	20-30	100	105	Millscale or similar iron oxide	Gasoline and chemicals
Entrained, fluidized-bed	Ditto	In use at Sasol	400[a]	300-340	25-30	100	105	Ditto	Ditto
Oil circulation	Pilot Plant	Development completed at Bureau of Mines	600	to 280	20-30	40	1.7	Fused iron oxide or steel lathe turnings	About 70% gasoline
Slurry	Ditto	Development continuing at Bureau of Mines and British Fuels Research Station	300	to 280	10-30	40	1.7	Precipitated or fused iron or millscale	50 to 70% gasoline
Hot-gas recycle	Ditto	Development continuing at Bureau of Mines	1600	300-340	20-30	50	4.8	Steel lathe turnings	Gasoline at operating temperatures of 300°C. or higher

[a] Includes disengaging space; about double this value on catalyst space.

of acceptable octane number. To produce gasoline of the high octane ratings (up to 100 CFR) required by modern automobiles, more drastic refining would be needed; presumably the entire liquid plus solid hydrocarbon products could be used as feed stock. The course taken will be influenced by automobile engine development in the future. Should the gas turbine or free piston engine be developed for use in automobiles, the paraffin oil, that is readily obtainable from Fischer-Tropsch synthesis, with its high heat of combustion would be attractive.

The cost of gasoline from coal by the Fischer-Tropsch synthesis was estimated by the National Petroleum Council in 1953 at about 30 cents/gal. (*24*). About 12 cents/gal. represented capital charges (6% return on investment, plus an equal amount for income tax) and the remainder manufacturing costs. The costs were based on a 27,000 bbl./day gasoline plant with a total investment of about $14,500/daily bbl. of oil, and included the costs of coal mine, start-up expense, and working capital, but did not include credit for byproduct chemicals. The total investment costs, without the coal mine, amount to $12,500/daily bbl.

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Field Benson Anderson

Joseph H. Field is acting chief, Gas Synthesis Section, U.S. Department of Interior, Bureau of Mines Central Experiment Station. He has published works on synthetic fuel, hot carbonate purification, and air pollution.

Robert Bernard Anderson is chief, Branch of Coal-to-Oil Research, Bureau of Mines. Active in ACS, he also is on the board of directors of the International Congress on Catalysis. Anderson received the Ipatieff Prize in 1953.

H. E. Benson is with the Research Department, Consolidated Natural Gas Company, working on developing processes for coal conversion. He was formerly with the Bureau of Mines.

Lee P. Morris

New data on the Gilsonite process

Development, design, and operation details for the Gilsonite refinery are presented now for the first time.

AMERICAN GILSONITE, AN AFFILIATE of the Barber Oil Corporation and the Standard Oil Company of California, made a major industrial advancement in the petroleum industry by starting up the first, large scale, privately financed project in the world to produce conventional petroleum products from a solid hydrocarbon called Gilsonite.

Several excellent papers have already described the geology of Gilsonite, the new hydraulic mining methods designed to remove the ore safely and efficiently from the earth, and the slurry pipe line to transport the solid material over rugged terrain to the refinery 72 miles away. These phases of the project have also been well documented in the trade and technical journals and many company periodicals (*1*). However, very little information has been published concerning the technical development, design, and operation of the refinery. This article is intended to shed some light on this important phase of the project.

The refinery processes approximately 4700 bbl./day of melted Gilsonite or 850 tons/day of Gilsonite on a dry basis with properties as shown in Table 1. From this feed material, 1600 bbl./day of an excellent quality motor gasoline, 600 bbl./day railroad fuel, and 310 tons/day of high grade electrolytic coke are produced.

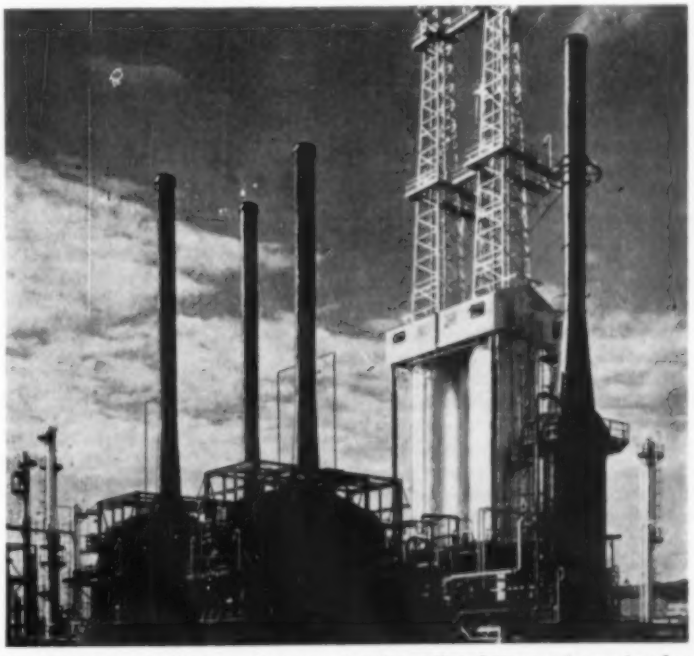
Table 1. Properties of Gilsonite.

Specific gravity at 60°F	1.05
Softening point (ring and ball) °F	350
Approximate ultimate analysis	
Sulfur, wt. %	0.3
Carbon, wt. %	85.0
Hydrogen, wt. %	10.0
Nitrogen, wt. %	2.0
Oxygen, wt. %	2.0
Approximate constituent analysis	
Asphaltenes, wt. %	63.0
Resin, wt. %	35.0
Oil, wt. %	2.0
Average molecular weight	1500

Flotation plant

Early in the refinery operation it was found that the ash content of the calcined coke was excessive. Since the coke ash content is a direct function of the ash content of the Gilsonite processed, an urgent program was initiated to determine the most feasible method of removing ash from the Gilsonite.

Three basic schemes were investi-



Delayed Coker at Gilsonite Refinery showing coker furnaces in center foreground, Melt Plant preheat furnace in right foreground, coke drums with derricks supporting decoking equipment in center background.

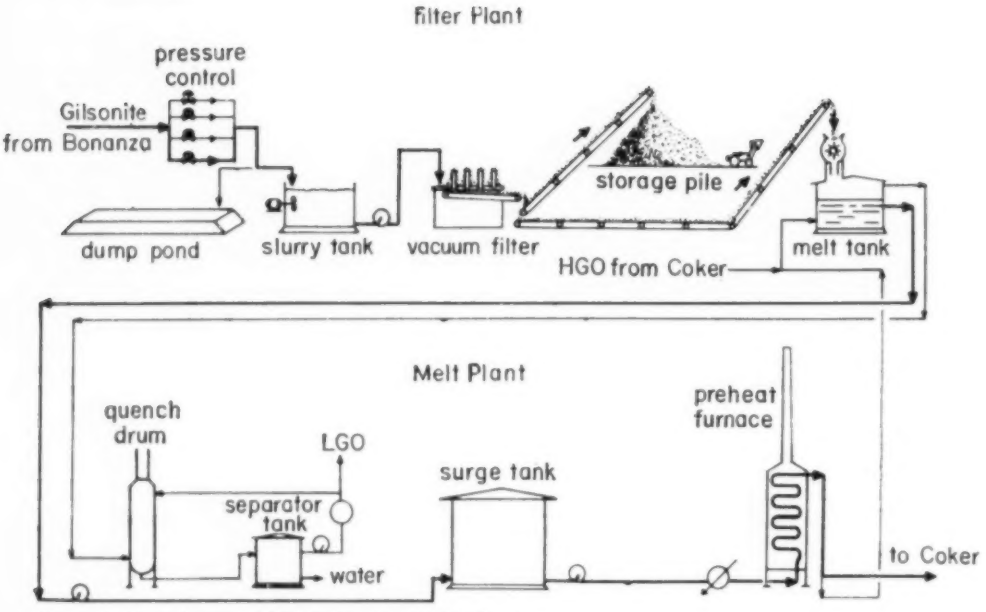


Figure 1. Flow diagram of Filter Plant and Melt Plant.

gated to remove the ash which is mainly in the form of the oxides of silicon, iron, calcium and trace elements barium, molybdenum, copper, cobalt, manganese, chromium, vanadium, and titanium. These are:

1. Removal of ash by filtering the combined melted Gilsonite and recycle stream feeding the coker.
2. Removal of ash by settling of the combined melted Gilsonite and recycle stream feeding the coker, followed by filtering the ash concentrated in the bottom of the settling vessel.
3. Removal of ash by use of flotation cells feeding slurry as received from the pipe line.

Field tests soon demonstrated extreme difficulty in filtering or settling and filtering micro size ash particles at elevated temperatures. Consequently, these schemes were discarded and extensive flotation cell tests started under the direction of the Colorado School of Mines Research Foundation. These tests proved the practicability of flotation cells to restrict the Gilsonite ash content below acceptable limits. Flotation cells were installed and have operated successfully now for several months. These cells process Gilsonite slurry as it is received from the pipe line.

Gilsonite is an ideal material for the flotation process because it has a natural surface condition which causes it to be readily attached to an air bubble and thereby floated. The ash contained with the Gilsonite does not attach to air bubbles. By taking advantage of this difference, a high proportion of the ash may be separated from the Gilsonite.

In order to obtain maximum selectivity of the wetted Gilsonite, it was found necessary to inject an additive such as methyl iso butyl carbinol. A commercial dispersal agent is also injected to disperse the bubbles so that a fluid froth forms on the surface of the flotation cells. In this froth bed a strong churning action occurs, and additional particles of the heavier ash trapped by mechanical action with the floated Gilsonite fall to the bottom of the cell. The Gilsonite froth is removed from the flotation cell as a product. The heavier ash with a surface condition not attracted to the air remains submerged in the cell or settles back after being released from mechanical entrapment and is eventually carried out to a bottom discharge opening as the cell tailings product. Gilsonite lost to the cell tailings system is only about 1% of the Gilsonite feed. The Gilsonite froth gravitates to a sump where the froth is mechanically broken by a propeller mixer to a slurry which is then pumped to the Filter Plant.

Filter Melt Plant

The Filter Plant, first step in a two stage dewatering operation, receives Gilsonite slurry pumped from the flotation cells (Figure 1). The slurry is filtered in a ten disc vacuum rotary filter. The filter cake, still containing approximately 15% moisture, is conveyed to a stockpile or to the Melt Plant.

About 12,000 tons of wet Gilsonite filter cake, a two weeks supply, are usually stockpiled at the refinery in case of a shutdown of the mine or pipe line (Figure 2). The filtrate water, which is crystal clear, is pumped to storage for re-use in the daily hydraulic decoking operation at the Delayed Coker.

The Melt Plant receives Gilsonite filter cake from the Filter Plant (Figure 1). The moist filter cake is conveyed to a feed hopper where it gravitates through star feeders into the melt tank. In the melt tank, residual moisture remaining in the filter cake is vaporized, and the solid Gilsonite melted at a temperature of about 425°F. Heat for this operation is supplied by recycling the mixture of Gilsonite and recycle gas oil through a furnace. A portion of this mixture is used as feed stock for the Delayed Coking Plant.

Light gas oil and water vaporized in the melt tank is condensed in a quench tower and recovered in a separator tank. The oil recovered in the separator tank is refluxed back to the quench tower as quenching medium. Excess oil is pumped to off test tankage where it is dehydrated and pumped to fuel oil or fed back to the Delayed Coker fractionator. Water recovered in the separator tank is dropped to the oily water sewer.

By means of the star feeders and a steam seal in the quench tower stack, the melt tank is maintained under a

Figure 2. Three week supply of wet Gilsonite filter cake being stockpiled at the refinery.

slightly positive pressure. This is important in order to avoid entry of air and formation of an explosive mixture in the melt tank vapor space. Normally a high percentage of steam in the melt tank vapor space precludes this, but an explosive mixture could possibly develop during periods when relatively dry filter cake is fed from the stockpile.

The Filter-Melt Plant system of dewatering and melting the Gilsonite was selected in favor of several other schemes. One scheme given serious consideration consisted of heating the Gilsonite slurry under pressure to temperatures above the melting point of the Gilsonite. With this scheme, the melted Gilsonite would be drawn off and the hot water flashed to steam, condensed, and re-used. This idea was discarded because of the difficulties in handling the carbonates precipitated by heating the hard water in the slurry.

Delayed Coker

The Delayed Coker receives its black oil feed from the Melt Plant furnace at about 600°F (Figure 3). The feed consists of a blend of recycle heavy gas oil and melted Gilsonite. Temperature of the feed is raised to about 900°F at which temperature thermal cracking readily proceeds. The amount of cracking which takes place is dependent on the temperature and the length of time the stock is held at cracking temperature.

The cracking reactions involve breaking of long chain hydrocarbons into two or more fragments. The fragments are more reactive than the uncracked feed because they contain a deficiency of hydrogen, and sufficient time at the high temperature permits many of the fragments to combine with one another forming heavier substances. These heavier substances can again be cracked. The process of breaking up and recombining contines as long as the materials are held at cracking temperatures. The resulting product contains materials covering the entire boiling range between hydrogen and carbon, including noncondensed gases, naphtha, gas oils, heavy fuel oil, and coke.

The function of the Delayed Coker is to promote these cracking reactions. This is accomplished by designing the coke drums to give a long residence time for the material at cracking temperatures and by designing the coking furnace to raise the feed to cracking temperatures rapidly to prevent coke from forming in the furnace tubes.

Coke formed in the coke drums during processing can be considered as a high molecular weight hydrocarbon, highly deficient in hydrogen. This coke is trapped in the coke drums and accumulates during each cycle. When the drum is taken out of service, the coke is cooled by steaming and finally by water quenching.

Lower molecular weight fragments from cracking, which escape from the coke drum as vapor, are separated in the fractionator according to their boiling points. The fractionator produces a gas product from which butane is recovered in the vapor recovery system, a raw gasoline product which is stabilized before going to storage as Catalytic Reformer feed, a light gas oil which is blended into railroad fuel or cracked in another furnance and returned to the fractionator, and a heavy gas oil and a tower bottoms which are sent to the Melt Plant to melt Gilsonite and returned with the feed to the coker. The heavy gas oil is also blended into railroad fuel as required.

Coke is removed from the coke drums by means of high impact water jets. The essential part of the hydraulic decoking equipment is the drilling system with boring and cutting tools. The coke in the drums is broken up by means of high velocity water jets from the nozzles of these tools, the necessary water velocity being produced by the extremely high discharge pressure (about 2150 lb./sq. in. gauge) from a jet cutting pump. A hollow drill stem of proper length is supported by a derrick over each coke drum. This drill stem carries the cutting tools the full distance from the top to the bottom of the

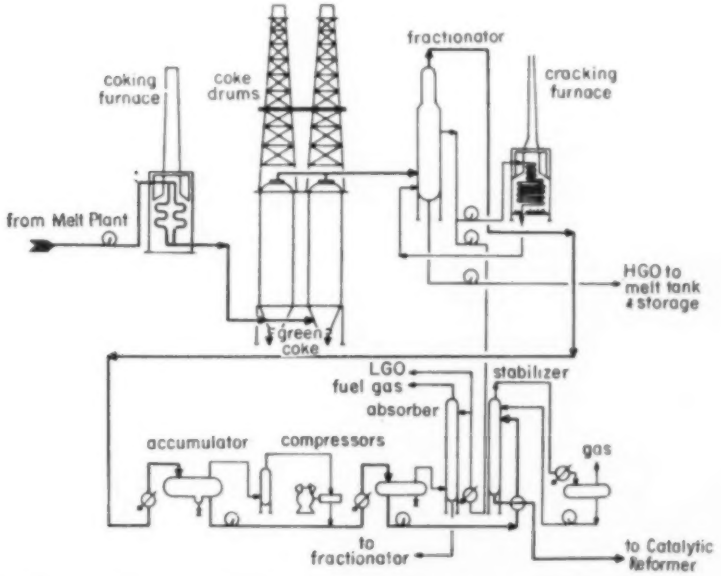


Figure 3. Coker flow diagram where melted Gilsonite is cracked forming green coke and feed for the Catalytic Reformer.

coke drum. The first boring tool cuts a pilot hole from the top to the bottom through the coke depth. The final cutting tool removes the coke from the drum by operating through the pilot hole. During the actual coke cutting operation, the drill stem and the cutting tools are rotated by means of a swivel joint which is driven by an air motor. Coke cut out of the coke drum falls onto a crushing car which crushes the coke to lumps two in. and smaller. The mixture of coke and water is then pumped to a decanting silo where the water is separated from the coke. The coke is then ready for calcining.

Serious corrosion problems have developed in the coker during the short time it has operated:

1. Corrosion occurred in the top of the fractionator and overhead condensing system. This problem has been solved by replacing the top of the fractionator with an 18-8-3 Cr-Ni-Mo clad section, the vapor line and condenser shells with the same alloy, and the trays with Incoloy.
2. Selective corrosion due to the presence of organic acids has occurred at points of high velocity and in a temperature range of 400°F in the light gas oil recycle systems. To date this attack has been confined to the light cycle pumps. The problem is being solved by improved metallurgy consisting of using 18-8-3 Cr-Ni-Mo wear rings, sleeves, and spacers in the pumps affected.
3. Hydrogen blistering has proven active in the vapor systems of the fractionator and stabilizer. Although Gilsonite is relatively low in sulfur, it is high in nitrogen, and the cyanides produced in the cracking process are excellent promoters of hydrogen blistering. This blistering is controlled by air-water injection into two points in the vapor recovery system.

Catalytic Reformer

The Catalytic Reformer may be divided into five units: the feed preparation section, the hydrogenation section, the Platforming section, the hydrogen generating plant, and the gasoline treating section. In normal operation the five units are closely interrelated. The purpose of the Catalytic Reformer is to convert a stabilized naphtha from the Delayed Coker into a finished motor gasoline with performance characteristics equal to or better than competitive products.

Naphtha produced from the Delayed Coker is unsuitable for motor gasoline because it is unstable and will form gum in storage and excessive deposits in engines; it contains undesirably high concentrations of nitrogen and sulfur compounds; and it does not have an octane number sufficiently high for use in the modern high compression engines.

The fraction of coker gasoline boiling at temperatures below 180°F has a high octane number and is a desirable constitutent of a motor gasoline. This part of the coker gasoline is separated in the feed preparation section. The nitrogen and sulfur contained in it are removed or are converted to more acceptable forms in the gasoline treating section. Inhibitor is also added to prevent gum formation and serve as a catalyst for gasoline sweetening. Treated light coker gasoline is blended with Platformate to make finished gasoline.

The coker gasoline contains a small amount of material boiling between 400° and 500°F. This heavy fraction is also removed in the feed preparation section as it is heavier than required in finished gasoline and will cause excessive coke formation and shorten the life of the expensive Platforming catalyst. This fraction is blended into railroad fuel.

Heart-cut of the coker gasoline is the part which can be most economically processed in the Catalytic Reformer and which will show the greatest octane number improvement. However, the sulfur and nitrogen compounds that it contains poison the expensive platinum catalyst. Furthermore, the olefin and the highly unstable components would cause increased coke laydown on the catalyst, short-

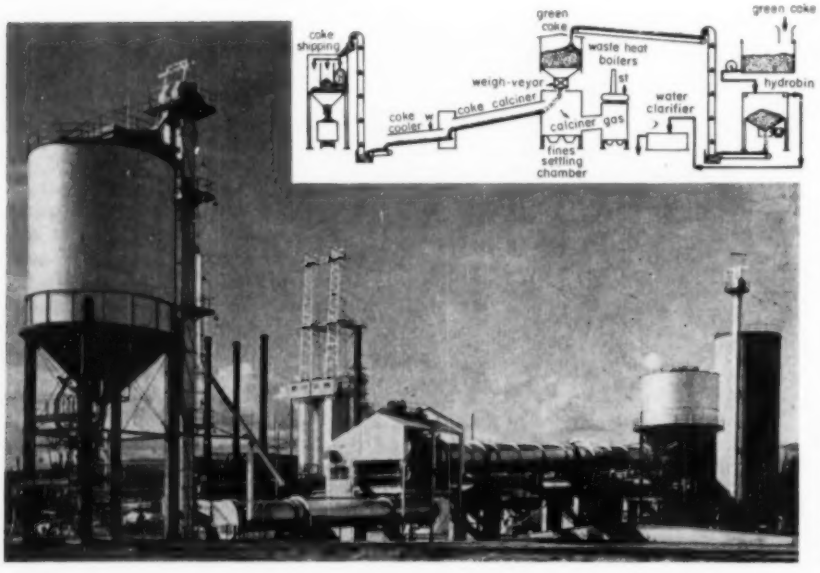


Figure 4. Illustrative diagram showing flow of green coke through the coke calciner operation where a high grade coke product is obtained. A low heat value by-product gas from this process is used as fuel for the boiler plant.

Figure 5. Actual coke calcining plant equipment for production of high grade coke at the Gilsonite refinery in Colorado is shown at left. The decanting and green coke silos are in the right foreground, the coke calciner and cooler are in the center foreground, and the product silo is in the left foregound. The green coke drums with the decoking equipment can be seen in the center background.

Lee P. Morris, manager of operations at the Gilsonite, Colorado, Refinery, of American Gilsonite Company, has been with the Standard Oil affiliate since 1955. Morris first joined Standard Oil of California in 1934, upon graduation from Caltech, where he received a degree in mechanical engineering. He has worked in various maintenance, construction, and process engineering executive assignments for the company, or one of its affiliates, ever since.

ening its life, and would cause excessive fouling of furnaces and other equipment at the high temperatures at which it must be processed. To avoid these difficulties it is necessary to hydrogenate the feed before Platforming to remove the sulfur, nitrogen, olefin, and gum-forming compounds. This is accomplished in the hydrogenation section.

The reactions occurring in the hydrogenation section consume hydrogen. Platformer excess hydrogen supplies part of the requirement. The remaining hydrogen is supplied from the hydrogen generating plant. In this plant, natural gas is mixed with superheated steam and passed over catalyst to form hydrogen and carbon dioxide. The carbon dioxide is removed by absorption in monoethanolamine solution. The purified hydrogen is pumped to the hydrogenation section to meet the hydrogen deficiency in that section.

In the Platforming section the following major chemical reactions occur:

1. Naphthenes release chemically combined hydrogen and form aromatics. The reaction is endothermic.
2. Paraffins and naphthenes are isomerized. Essentially no heat is absorbed or given off in this reaction.
3. Paraffins are cracked into smaller fragments with the addition of hydrogen. This is called hydrocracking. The reaction is exothermic.
4. Paraffins release hydrogen and change to aromatics. This is dehydrocyclization. The reaction is endothermic.

Table 2. Typical inspections of finished premium gasoline.

Sulfur content, wt. %	.02
Octane number,	
Test F-1 + 2cc TEL	96.5
Gum content, mg./100 ml.	Trace
Induction period,	
pressure break, hr.	50+
Gum after 6 hr. induction, mg.	2
Component analysis	
olefins, %	10.0
paraffins, %	58.0
aromatics, %	32.0

The result of the above reactions is the formation of chemical compounds having higher octane numbers than the compounds from which they originated. In addition to the high octane product there is a net production of hydrogen gas which is recycled to the hydrogenation section. Some light hydrocarbon gases, which are not useful gasoline components, are formed by hydrocracking and removed in the stabilizer.

Gasoline manufactured from Gilsonite is an exceptionally clean and highly stable motor fuel with an excellent road octane rating. Typical inspections of the finished premium gasoline are shown in Table 2.

Calciner

The Calciner Plant produces a high purity electrode coke. A by-product of the process is the production of a low heating value gas which is used as fuel for the boiler plant.

Wet green coke is received in the decanting silo from the coker. The coke is then conveyed to the green coke storage silo (Figures 4 and 5). The green coke leaves the storage silo by gravity and is metered into the rotary kiln where it is calcined. The calcining operation removes the volatile combustible matter from the coke by heating it to a temperature of about 2300°F. The rotary kiln is a 10-ft. diam. by 180-ft. long cylindrical steel shell lined with refractory. The kiln is sloped ¾ in./ft. and revolves at 1 rev./min.

The coke leaving the calciner is cooled to approximately 300°F in a rotary cooler by water sprays. The cooled coke having properties shown in Table 3 is then weighed and conveyed to a storage silo for subsequent shipment. The rotary cooler is 8 ft. in diam. by 80-ft. long and revolves at 3 rev./min. The dust entrained in the water vapor leaving the cooler is removed in a dust collector, and the vapor exhausted to the atmosphere.

The gases leaving the kiln are a mixture of flue gases from the burner plus the hydrocarbons in the volatile matter leaving the coke. These gases pass through a gravity settling chamber where most of the entrained coke dust is removed, then proceed into the boilers where the volatile combustible matter is burned. The draft required to pull the gases through the calciner and boiler is provided by the induced draft fans located at the gas exits of the boilers.

Table 3. Typical inspections of calcined coke.

Real density	2.03
Resistivity, ohm/cu. in.	0.035
Grindability index	22.0
Moisture, wt. %	0.02
VCM, wt. %	0.20
Fixed carbon, wt. %	99.4
Sulphur, wt. %	0.20
Ash, wt. %	0.40
Silicon	0.03
Iron	0.03
Calcium	0.04
Aluminum	.02
Magnesium	.01
Nickel	.05
Trace elements, wt. %	
Barium	.0003
Molybdenum	.0005
Copper	.0003
Cobalt	.004
Manganese	.0005
Chromium	.001
Vanadium	.0004
Titanium	.003

One rather interesting problem has developed in operating the calciner. When the waste gases are burned in the boilers, fire box combustion pulsations develop, causing serious high amplitude vibrations of both boilers and adjacent structures. An intensive study to determine the reason for these pulsations showed they could be virtually eliminated by removing the symmetrical flow pattern of the waste gases. Thus if the waste gases are burned under one boiler only or if the gases are throttled into one boiler and flow unrestrained into the second fire box, the pulsations do not develop.

American Gilsonite now produces three standard petroleum products from the solid hydrocarbon known as Gilsonite. The Company is currently surveying the possibilities of making other petroleum products, including the manufacturing of specialities, and is engaged in an expansion program to increase the refinery capacity to 1100 tons/day.

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E. M. Blue and B. Spurlock

Cobalt-moly catalyst

The most effective means of removing platinum catalyst poisons in a one-step operation is by hydrogenation over a cobalt-moly catalyst.

Whether or not there is good reason for the steady increase in automobile horsepower, which demands higher and higher octane gasoline, it nevertheless presents a problem to the petroleum refiners who must keep pace with today's engine fuel requirements. Over the past ten years, reforming over platinum catalyst has been the principal new process used by refiners to meet the increased octane demands. At first, the refiner reformed only his heavy straight run naphtha and processed it to 90 F-1 clear octane. Now, he must also reform cracked stocks as well as straight run, and to 95 F-1 clear, or higher. The necessity for reforming more severely and for reforming stocks containing platinum catalyst poisons, such as olefins, sulfur, nitrogen, and arsenic, has resulted in the need for treatment of these stocks prior to reforming over platinum. There are several ways to remove the individual poisons. However, the most effective means of removing them all in one step is by hydrogenation over cobalt-moly catalyst*.

Platinum catalyst poisons

Nitrogen, or the ammonia which is formed from nitrogen compounds, attacks platinum catalyst acid sites and thus reduces isomerization and hydrocracking activity with little effect on dehydrogenation activity.

* *The name "cobalt-moly" refers to the alumina-base catalyst containing cobalt oxide and molybdenum oxide. Except where noted, the catalyst used in the commercial and pilot plant tests reported in this paper is Oronite Hydrogenation Catalyst, whose properties are shown in Table 1.*

Sulfur poisoning of platinum catalysts was recognized in the early days of catalytic reforming. Sulfur poisons dehydrogenation activity but has less

Table 1. Oronite hydrogenation catalyst.

Chemical composition (moisture-free) weight percent	Typical inspections
CoO	3.5
MoO_3	10.0
Cl	0.04
Fe_2O_3	0.07
Na_2O	0.01
C (graphite)	4.0
Volatile matter, 1200°F for 1 hr.	1.0
Physical properties	
Pellet size, in.	3/16
Surface area, (N_2), sq. m./g.	143
Bulk density, g./ml.	1.02
Crushing strength, lb. (flat plate method)	43

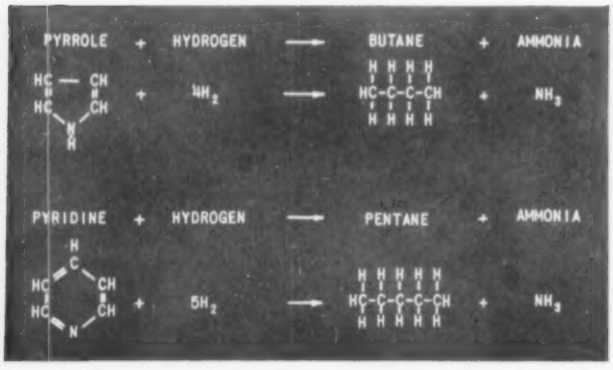

Figure A. Hydrogenation of nitrogen compounds.

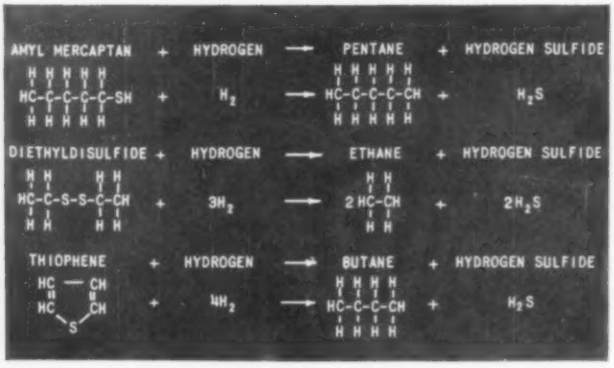
AMYL MERCAPTAN + HYDROGEN → PENTANE + HYDROGEN SULFIDE
+ H2 → + H2S
DIETHYLDISULFIDE + HYDROGEN → ETHANE + HYDROGEN SULFIDE
+ 3H2 → + 2H2S
THIOPHENE + HYDROGEN → BUTANE + HYDROGEN SULFIDE
+ 4H2 → + H2S

Figure B. Hydrogenation of sulfur compounds.

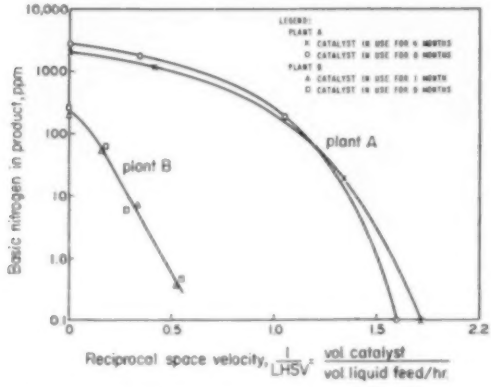

Figure 1. Nitrogen removal over cobalt-moly catalyst. Commercial results using Oronite Hydrogenation Catalyst (OHC); 250-400°F boiling range naphthas; at 800 lb./sq.in.ga.

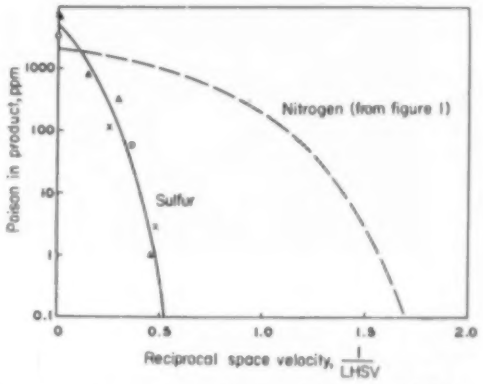

Figure 2. Sulfur removal over cobalt-moly catalyst. Pilot plant and commercial results using OHC; 250-400°F boiling range naphthas; at 800 lb./sq. in.ga., 750°F.

effect upon isomerization activity. Sulfur is also a source of corrosion, particularly in regenerative reforming, where the alternate oxidation and reduction of sulfide scale cause it to break loose and plug catalyst beds.

Olefins will cause heavy carbon deposition if processed over platinum catalyst under usual operating conditions. Olefins can be hydrogenated over platinum at low temperature, but at the 900°F level they cause severe coking.

Arsenic is a permanent poison to platinum catalysts. Unlike sulfur, arsenic does not spread throughout the catalyst at once but is removed preferentially by the first catalyst it meets and then gradually spreads through the system.

Chlorides are sometimes added to reformer feed stock in small, controlled amounts to maintain the acidic activity of the catalyst. However, if large amounts of chloride appear in the feed, the acidic activity of the catalyst will become overstimulated and can result in severe hydrocracking.

Many other compounds have been declared injurious to the activity of platinum catalyst including copper, lead, nickel, sodium, oxygenated compounds, and water.

Removal of poisons

There are many ways of removing individual platinum catalyst poisons. For example, the methods of removing sulfur:

1. Sulfur compounds can be completely converted to hydrogen sulfide over cobalt-moly catalyst.
2. Part of the sulfur compounds can be converted to hydrogen sulfide over bauxite or hot clay.
3. Part of the sulfur compounds can be removed by acid treating.
4. The hydrogen sulfide concentration in the reformer can be reduced by scrubbing hydrogen sulfide from the recycle gas stream.

Similarly, there are several ways to remove nitrogen compounds, arsenic, and the others. The type of treatment used depends on the number and concentration of poisons in the reformer feed stream. Hydrogenation over cobalt-moly catalyst is preferred where: there are several poisons present, concentration of any one or more poisons is very high, or complete removal of all the poisons is

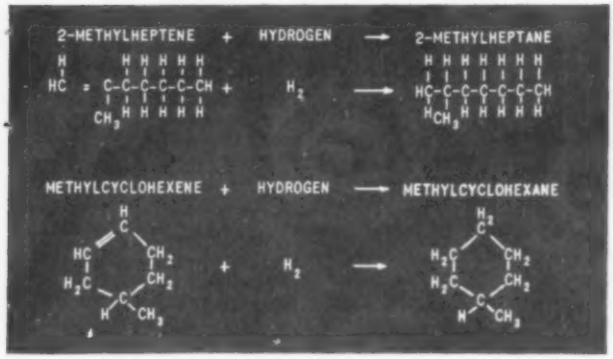

Figure C. Hydrogenation of olefins.

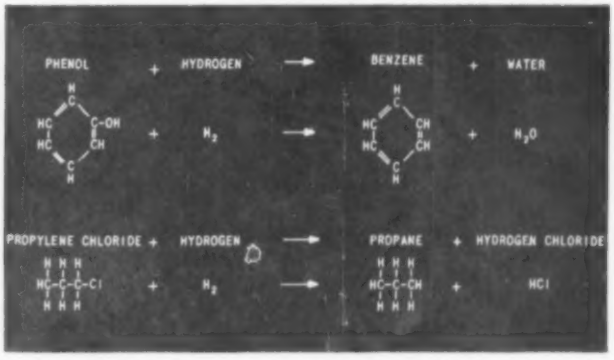

Figure D. Hydrogenation of oxygenated compounds (upper) and chlorinated compounds (lower).

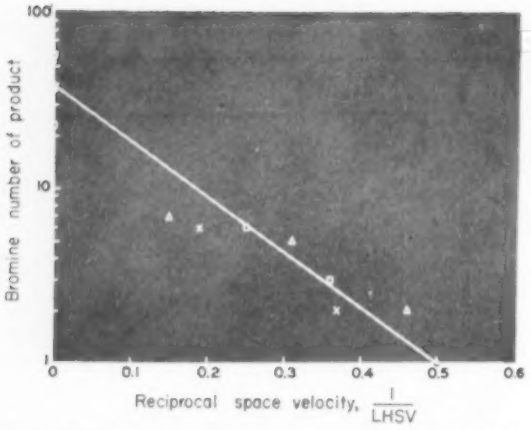

Figure 3. Olefin hydrogenation over cobalt-moly catalyst. Pilot plant and commercial results using OHC; 250-400°F boiling range cracked naphthas; at 800 lb./sq.in.ga., 650-750°F.

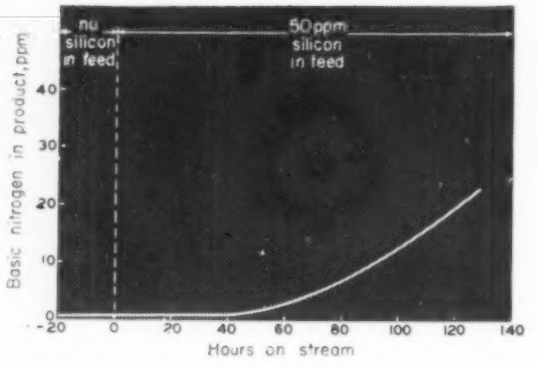

Figure 4. Effect of silicon on nitrogen removal over cobalt-moly catalyst. Pilot plant tests using OHC; 275-435°F boiling range naphtha and 350 ppm basic nitrogen; at 800 lb./sq.in.ga., 750°F, 4 LHSV.

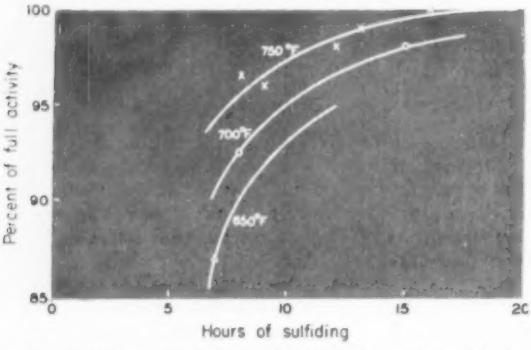

Figure 5. Effect of sulfiding fresh cobalt-moly catalyst. Laboratory tests on OHC; 200-400°F naphtha containing 0.86 wt.-% sulfur; at 800 lb./sq.in.ga., 2 LHSV, 3000 scf/bbl. hydrogen recycle.

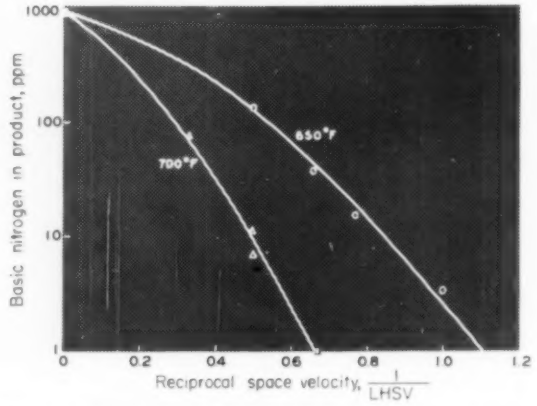

Figure 6. Effect of temperature on nitrogen removal over cobalt-moly catalyst. Pilot plant results using OHC; 250-400°F boiling range naphtha; at 800 lb./sq.in.ga.

necessary for maintaining high platinum catalyst activity.

Performance of cobalt-moly catalyst

The ability of cobalt-moly catalyst to remove all of the above-mentioned platinum catalyst poisons has been demonstrated by both commercial and pilot plant operations. Part of the effectiveness of the catalyst is its ability to convert poisons into a form that can be easily removed from the hydrogenated product prior to reforming, or into a form that is harmless to the platinum catalyst. Examples are the reactions involving nitrogen-, sulfur-, olefin-, oxygen-, and chloride-containing compounds which are shown in Figures A, B, C, and D. The ammonia, hydrogen sulfide, water, or hydrogen chloride formed in these reactions can be removed from the reformer feed by water washing and distillation. The saturated compounds formed by hydrogenating olefins can be charged directly to the platinum catalyst.

Metal poisons, such as arsenic, silicon, lead, etc., are held to a large extent by the cobalt-moly catalyst after decomposition of the metal-organic compounds. No further processing of the hydrogenated stock is necessary, as far as these compounds are concerned, before the stock is fed to the platinum catalyst reformer.

Nitrogen. Denitrification over cobalt-moly catalyst occurs by conversion of nitrogen compounds to ammonia according to reactions of the type shown in Figure A. As ammonia is also a platinum catalyst poison it must be removed from the naphtha before it is fed to the reformer. This is done by water washing the product for removal of most of the ammonia and then stripping or distilling out the residual traces. By water washing the whole reaction mix, ammonia is also removed from the recycle gas.

Nitrogen is the most difficult contaminant to remove from reformer feed stocks. The denitrification rate over cobalt-moly catalyst is much slower than that for desulfurization. Processing severity is, therefore, dictated by the presence of nitrogen compounds in reformer feeds. If the nitrogen compounds are removed over cobalt-moly catalyst, all other platinum catalyst contaminants are also removed.

The fact that nitrogen compounds are the most difficult to break down over cobalt-moly catalysts provides a convenient index for testing these catalysts. A measure of activity is the amount of residual basic nitrogen

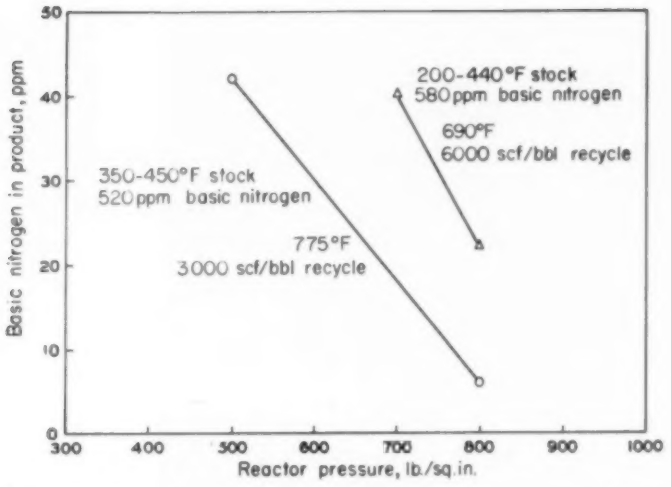

Figure 7. Effect of pressure and temperature on nitrogen removal over cobalt-moly catalyst. Pilot plant results using cracked naphthas at 2 LHSV.

compounds in the product. It is recognized that this does not show the total nitrogen content; however, after normal treatment of a stock containing both basic and nonbasic types of nitrogen compounds over cobalt-moly catalyst, the only nitrogen compounds remaining, if any, are basic. Furthermore, the analytical procedures for determining basic nitrogen compounds are quick and accurate, while the tests for total nitrogen are relatively slow.

Figure 1 shows commercial data on denitrification of reformer feed stocks over cobalt-moly catalyst. The data show an operation in which the nitrogen content of a reformer feed stock is reduced from over 2500 ppm to less than 0.1 ppm. These data are from multiple-reactor plants, and the data are for samples withdrawn between reactors.*

Sulfur. The most widespread use of cobalt-moly catalyst is for removal of sulfur from a broad range of hydrocarbons, such as coke oven tar, stove oil, kerosene, jet fuels, and many other stocks. Sulfur compounds in naphthas are readily converted to hydrogen sulfide over cobalt-moly catalyst. Figure 2 shows both commercial and pilot plant desulfurization results. As mentioned previously, the desulfurization rate is much faster than the denitrification rate. This is illustrated by one of the nitrogen lines from Figure 1, which is also shown in Figure 2.

Desulfurization occurs by conversion of sulfur compounds to hydrogen sulfide according to reactions of the type shown in Figure B. The hydrogen sulfide formed is removed by stripping or distillation. If nitrogen compounds are present, a part of the hydrogen sulfide will react with ammonia to form ammonium sulfide, which is removed by water washing the reaction mix.

Olefins are hydrogenated over cobalt-moly catalyst by reactions of the type shown in Figure C. These reactions are exothermic, and due allowance must be made for the increase in temperature that occurs. In some instances, where the stocks being processed are highly olefinic, such as those from cracking or coking operations, the heat release is so high that the reacting mixture must be quenched to prevent excessive temperature rise. Figure 3 shows the hydrogenation of olefins, as measured by bromine number, in commercial and pilot plant operations.

Arsenic is removed quantitatively from reformer feed stocks by cobalt-moly catalyst. Complete removal of arsenic from feed stocks containing 50-500 ppb has been observed in commercial operation. Up to 0.45

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* *The shape of the curves in Figure 1 deviates from a straight line that would be expected from an isothermal reaction for two reasons: (1) the feed stocks are cracked naphthas, and the first reactors are run at lower temperatures to allow for the heat release from olefin hydrogenation; (2) the nonbasic nitrogen compounds are first converted to basic nitrogen compounds. This slows down the over-all reduction in basic nitrogen compounds until all the nonbasic nitrogen compounds have been converted.*

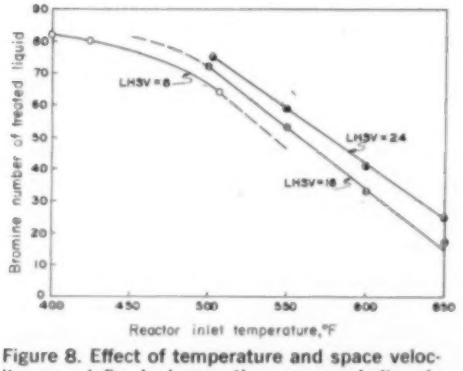

Figure 8. Effect of temperature and space velocity on olefin hydrogenation over cobalt-moly catalyst. Pilot plant results: 200-265°F cut from thermal cracked naphtha; at 800 lb./sq.in.ga.

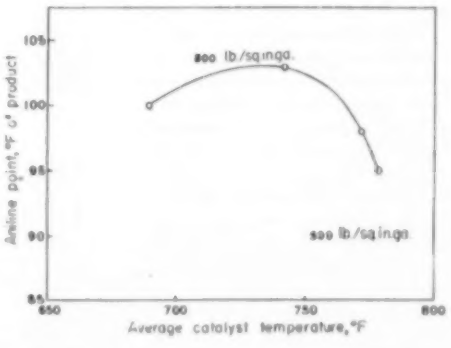

Figure 9. Effect of temperature on reforming over cobalt-moly catalyst. Pilot plant results using 350-450°F cracked naphtha.

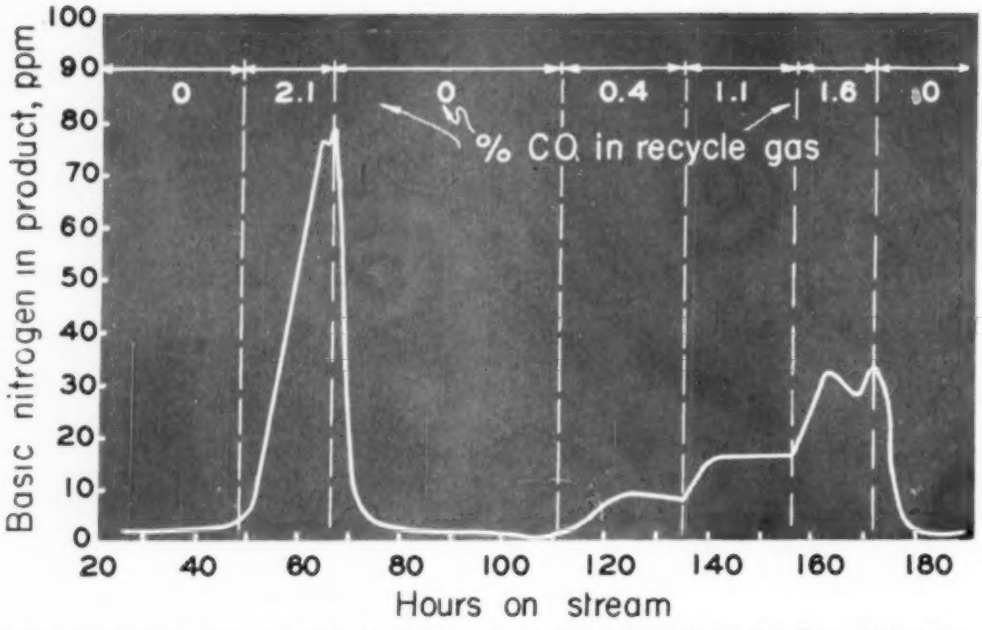

Figure 10. Effect of carbon monoxide on nitrogen removal over cobalt-moly catalyst. Pilot plant results using OHC; 300-430°F boiling range naphtha and 365 ppm basic nitrogen; at 800 lb./sq.in.ga., 4.5 LHSV, 775°F max., 3000 scf/bbl. gas recycle.

wt.-% As has been found on active cobalt-moly catalyst removed from the first reactor of commercial units.

Lead is also removed almost quantitatively from reformer feed stocks by cobalt-moly catalyst. In a laboratory test, Oronite catalyst reduced Pb concentration from 1000 ppm to less than 0.1 ppm, Up to 0.9 wt.-% Pb has been found on active cobalt-moly catalyst removed from the first reactor of a commercial unit.

Silicon. Silicones are frequently used for foam breakers in refining operations. Laboratory tests show these silicones will decompose in cracking operations, and some volatile silicon products are formed in the naphtha boiling range. Because of the concern that silicon might poison a platinum catalyst, a series of laboratory tests was made to determine the effectiveness of cobalt-moly catalyst for silicon removal. Figure 4 shows results of these tests. A naphtha containing 350 ppm of basic nitrogen was processed over cobalt-moly catalyst for 20 hr. Then, 50 ppm of organic silicon compounds (formed by thermal decomposition of silicones) was added to the feed. During the next 60 hr. of operation, the removal of both N and Si was essentially complete. In the ensuing period, the catalyst started to lose activity, as evidenced by increasing N in the product and the appearance of Si compounds in the product. This test, and others, show the catalyst still has half of its original activity after adsorbing over 2 wt.-% Si. The test also shows that Si will be removed by the first part of the cobalt-moly catalyst bed, thus preserving the activity of the afterpart of the bed.

Effect of operating conditions

Although cobalt-moly catalyst is effective in removing contaminants from catalytic reformer feed stocks, there are several factors affecting its efficiency.

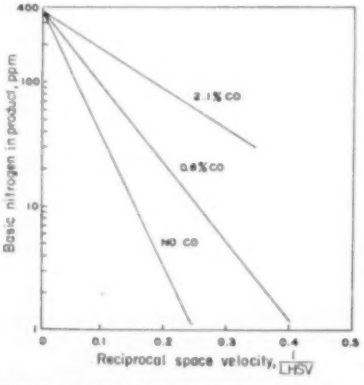

Figure 11. Effect of carbon monoxide on nitrogen removal over cobalt-moly catalyst. Pilot plant results using OHC; 300-430°F boiling range naphtha and 365 ppm basic nitrogen; at 800 lb./sq. in.ga., 760°F, 3000 scf/bbl. gas recycle.

Sulfiding cobalt-moly catalyst. The cobalt and molybdenum in fresh or regenerated cobalt-moly catalyst are in the oxide form, and the catalyst is not fully effective until the oxides are converted to sulfides. Figure 5 shows laboratory tests on sulfiding catalyst before use. In these tests fresh catalysts were sulfided for varying periods and with increasing temperature by processing a naphtha containing 0.86 wt.-% S at 2 LHSV*. It will be noted that the catalyst developed full activity only after sulfiding for about 15 hr. at 750°F. Based on these tests, the standard laboratory procedure is to sulfide fresh or regenerated cobalt-moly catalyst for a comparable period before any activity tests are run.

In commercial operation, the period necessary for developing full activity of the catalyst will depend upon the sulfur content of the feed.

Process variables. Desulfurization, denitrification, and olefin saturation over cobalt-moly catalyst are enhanced by increasing temperature and pressure or by decreasing space velocity.

Figures 6, 7, and 8 confirm the increased conversion with increasing temperature and pressure and with decreasing space velocity. Figure 7 shows the large effect that high pressure has on nitrogen removal. Figure 8 shows the conversion begins at

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* *Liquid hourly space velocity.*

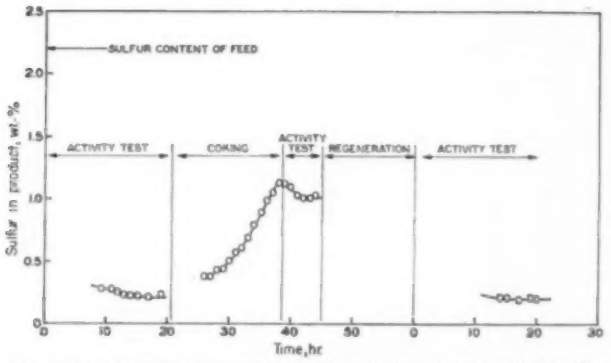

Figure 12. Steam-air regeneration of cobalt-moly catalyst desulfurizing Safaniya gas oil. Laboratory test using OHC.

about 450°F and increases progressively with increasing temperature. However, it must be remembered that molybdenum catalyst is also a good reforming catalyst and, in fact, is used as such today in fluid hydroformers and in some fixed bed hydroformers. At temperatures above 750°F, some naphthenes will dehydrogenate over cobalt-moly catalyst to form aromatics; this is illustrated on Figure 9,* which shows aniline point of the product at increasing processing temperatures. Aniline point varies inversely with the aromatic content of the product. It will be noted that the aniline point begins to drop at temperatures above 750°F, indicating formation of aromatics. Notice, also, that reforming increases as pressure is lowered. Processing reformer feed stocks over cobalt-moly catalysts at temperatures much above 750°F is undesirable because the cobalt-moly catalyst is not as selective a reforming catalyst as is platinum catalyst and because coke may be deposited on the cobalt-moly catalyst, necessitating regeneration.

Carbon monoxide. Carbon monoxide will poison cobalt-moly catalyst temporarily. Figure 10 shows the poisoning effect of varying CO concentrations in the recycle gas and shows the very rapid response by the catalyst to addition or removal of CO. As shown, a stock containing 350 ppm basic nitrogen was processed under conditions that reduced the basic nitrogen in the product to about 2 ppm. After operating for 50 hr., CO was added to the make-up hydrogen until its concentration in the recycle gas was 2%. The rapid decline in catalyst activity until the carbon monoxide was removed and then the rapid recovery of full activity is evident in Figure 10. Similarly, small increments of CO caused incremental losses of catalyst activity. Again, when CO was removed, the activity was rapidly restored. Figure 11 summarizes results of a series of runs made to show the space velocity changes required to compensate for activity loss by CO poisoning.

Carbon deposition. Cobalt-moly catalyst loses activity if carbon is deposited on it. However, if reformer feed stocks are processed under the proper operating conditions, carbon deposition is not a problem. On the other hand, if insufficient catalyst or pressure is provided in a given installation, it may be necessary to process at reforming temperature—say, above 750°F—to clean up the stock. Under these conditions, the catalyst will coke, necessitating periodic regeneration.

Since naphtha treatment under proper operating conditions does not coke the catalyst rapidly, a more severe treatment was used in the laboratory to demonstrate regenerability. Figure 12 shows the results of this test. A Safaniya gas oil containing 2.2 wt.-% S was processed over the catalyst under conditions that reduced the sulfur content to 0.2 wt.-%. Then the catalyst was purposely coked by processing under severe conditions of high temperature and low hydrogen-recycle rate. At the end of this coking period, the coke laydown was 13% of the catalyst weight. An activity test showed a substantial loss in catalyst activity. The catalyst was then regenerated with a steam-air mixture, after which another activity test was run under the same conditions as the previous two.

It can be seen in Figure 12 that the activity of the catalyst was fully restored after the regeneration. Activity testing was at 750°F, 800 lb./sq.in.ga., 1 LHSV, and 3000 scf/bbl. of hydrogen recycle. The coking period was at 850°F with hydrogen recycle reduced to 300 scf/bbl. A steam-air mixture, starting with 1% oxygen and 900°F inlet temperature, was used for regeneration. Maximum catalyst temperature during regeneration was 1050°F.

Conclusion

Platinum reforming catalysts are susceptible to poisoning by several compounds normally found in reformer feed stocks. Cobalt-moly catalyst, on the other hand, is very resistant to poisoning and is capable of removing all of the components that poison a platinum catalyst. The cobalt-moly is poisoned only slowly by the few materials that affect it at all. Because of these attributes, it is widely used in the petroleum industry where very clean feed stocks are required for reforming over platinum to high octane levels.

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The authors wish to acknowledge the work of Messrs. A. S. Brengle, J. J. Brodbeck, S. S. Cima, W. M. Haunschild, R. J. Houston, and R. S. Tolberg for the laboratory results reported herein. The authors also wish to express their appreciation to the California Research Corp. for permission to publish these results.

Blue Spurlock

E. M. Blue is with Standard Oil Company of California. His current work is coordinating technical service for the catalytic reforming and catalytic cracking units in the refineries. Blue is a graduate of Massachusetts Institute of Technology and the University of California.

Burwell Spurlock is with California Research, San Francisco. His present post is supervisor of catalytic reforming process development. Spurlock attended Grinnell College and the University of California.

* *The data in Figures 7, 8, and 9 are earlier results obtained on a cobalt-moly catalyst that was available before the introduction of Oronite Hydrogenation Catalyst.*

Rocketdyne photo

G. C. Szego

Free radical fuels

Still looking for exotic energy sources? Consider free radicals.

One of man's deep-seated instincts is to control and dominate his environment. Dominion over matter through control of energy is a permanent facet of human nature. Ubbelohde in his book *Man and Energy* (*1*), speaks of the era beginning about 1700 A.D. as "The new era of inanimate energy in the service of man." In the very small slice of history that has elapsed since then, profound trends have been established which may be summed up by saying that a nation which is rich in stores of energy and has developed its technology to such a point where it can efficiently utilize these resources is a nation both wealthy and powerful. For one reason or another, military capability becomes a necessity for national security in the family of nations. This has a very close connection with both the extent of energy resources and the capability of man to apply them efficiently.

It is quite clear that the United States does not have a monopoly on energy reserves. For example, world coal resources measured in Q, or 10^{18} Btu, as estimated by Sir John Cockcroft in 1953, are shown in Table 1 (*2*).

Table 1.

Nation	Q
USSR	10
USA	7.6
China	6
Canada	2
UK	1
Others	7
Total	33.6

Proven world oil resources amount to 1 Q, with perhaps a further 4.6 Q of unproven oil reserves. At \$100 a pound for uranium, assuming breeding and 100 percent utilization, we may count on another 1700 Q. However, if we wish to pay only \$50 a pound, we can allow for only 250 Q. It has been estimated that the needs of the United Kingdom could be met with 50 tons of uranium a year at a primary fuel cost of less than \$10 million.

A particularly hungry sink for man's energy supply is that which degrades energy for purposes of flight propulsion. One rapidly emerging truism which we are now beginning to realize is that the number and extent of capabilities of this nation's air and extraterrestrial weapons systems is perhaps the most important inanimate national asset. It may be helpful to state that to deliver a small hydrogen bomb only 1500 miles away requires 80 million Btu of energy. The average 12,000-

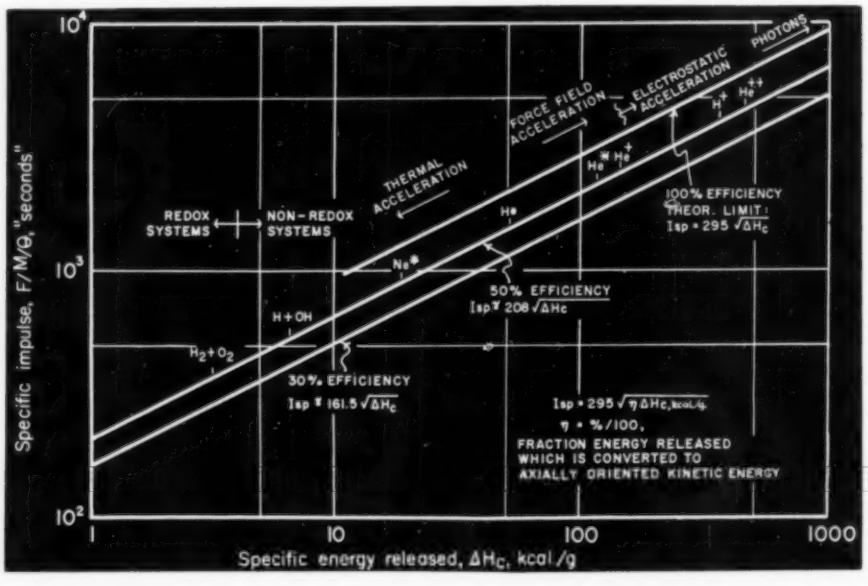

Figure 1. Specific impulse as a function of fuel energy content.

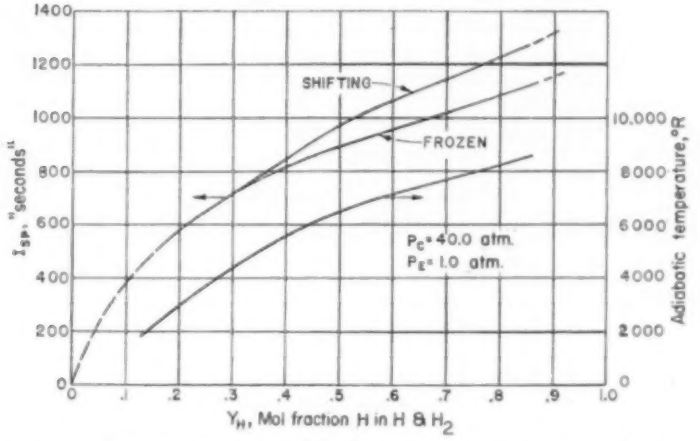

Figure 2. Performance and temperature parameters vs. composition of hydrogen free radical in H_2, without oxidizer.

mile round-trip of one B-52 gulps 7.5 billion Btu. These figures, it should be noted, do not consider the great inefficiencies and energy costs of manufacturing and stabilizing the fuels utilized. The entire jet fuel production of the U. S. is equivalent to about 7×10^{14} Btu/yr.

At the outset it is well to distinguish between a source and a temporary repository of energy. We should recognize that all of our energy supply is dependent upon the original source. The only useful distinction we may place on modes of deriving energy is whether a given energy source is energetic before this energy is discharged for (and at) our convenience, or whether this energy must be applied to the source at some time prior to its release.

In the first category, one which we may term a true "source," we may place such things as petroleum, coal, elevated mass, and nuclear fuels. In the second group, one we might call a "repository," we may place storage batteries in the uncharged condition, electrical capacitors, a mass at the reference plane, an uncoiled spring, and the like. In a unique third position is the sun, in that it is a continuing source of energy, but not one from which energy can be released or stored at will.

Except in their relation to radiant energy from the sun, free radicals distinctly belong in the repository classification. With this distinction in mind, we may explore the place played by free radicals and metastable states in the energy spectrum at man's disposal.

A free radical may be defined as any fragment of a stable molecule which consists of at least one atomic species, which fragment is both electrically neutral and unstable in its uncombined state. An example would be atomic hydrogen, illustrated by

$$H_2 \longrightarrow 2\,H\cdot; \quad +117 \text{ kcal./g. mole}$$

and has all the inherent characteristics of any dynamic chemical system, *i.e.* that the equilibrium amount of dissociated H· is a function of the temperature, and indirectly, of the pressure and the presence of diluents.

Free radicals were originally postulated by Liebig in 1828. He visualized them as submolecular units which took part in chemical reactions as a group rather than via the individual atoms involved. In 1900, Gomberg, at the University of Michigan, first isolated and clearly proved the presence of free radicals in the realm of aromatic, organic chemistry. Following this discovery a great deal of experimental work was carried out, probably the best known being that of Paneth and Hofeditz (3) at Berlin in 1929, dealing with the deposition and removal of metallic mirrors by aliphatic free radicals, chiefly methyl, $CH_3\cdot$.

Since that time, research into the free radical area has been concerned mainly with kinetics and mechanism, and an elucidation of the nature of the processes, such as polymerization, which may be dependent upon free radicals in some manner.

With the extreme emphasis recently placed on developing rocket propellants of increased performance capability, attention has been focused on the possibility of employing free radicals. Roughly, the range of a given rocket vehicle is directly proportional to the energy release per unit mass of propellant. Hence, range is also proportional to the square of the specific impulse. Consequently, markedly improved rocket propellants will have to deliver substantially greater specific energy release.

A convenient parameter widely used in the field of rocket propulsion is called the "specific impulse". This is defined as the thrust force obtained from a unit mass flow rate of total propellants:

$$I_{sp} = \frac{F}{\dot{W}} = \frac{\infty}{g_o} = \frac{V_e}{g_o}$$

This is approximately equal to the exhaust velocity divided by the gravitational constant. I_{sp} has units of

$$\frac{\text{(force) (time)}}{\text{(mass)}}$$

and is commonly, though mistakenly, referred to as having time units only, *i.e.* "seconds". The specific impulse is roughly proportional to the square root of the specific energy release.

No chemically reacting system (in which chemical bonds are broken and new ones formed), called for convenience "Redox Systems" is known which is capable of releasing substantially greater specific energy than about 4 kcal./g., Figure 1. Nonredox systems have been proposed which substantially exceed this figure.

Table 2 summarizes the theoretical specific energy release capabilities for a number of nonredox systems. A complete and quantitative study of the theoretical performance capabilities of free radicals has been carried out at the General Electric Company for the National Bureau of Standards. Those systems which appeared important for thermodynamic or performance reasons were investigated in some detail. This work is fully reported elsewhere (*4, 5*).

Of the pure free radical systems, only the system H·, H_2 shows a truly attractive performance capability. Figure 2 shows the specific impulse, both frozen and shifting, for the H·,

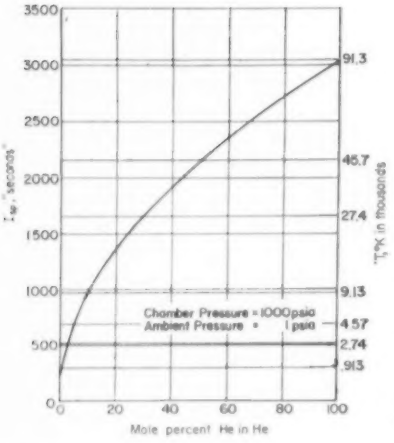

Figure 3. Specific impulse, I_{sp}, as a function of metastable helium (He*) concentration.

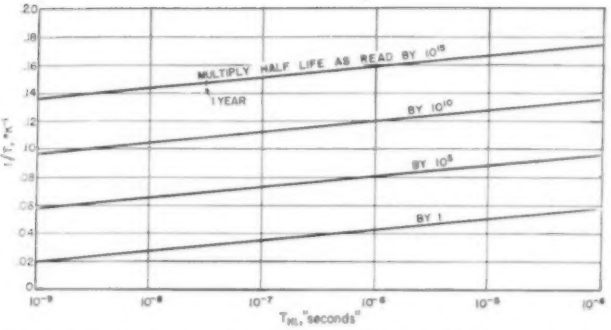

Figure 4. Half life of metastable neon (Ne*) at 300 lb./sq. in.

H_2 system as a function of initial H• concentration, expanded from 40 to 1 atm. The adiabatic equilibration temperature as a function of composition is also shown. It can be seen that it is only at 0.1 mol fraction (or 10% of H•) that this system begins to exceed in theoretical performance the best redox propellants (*4, 5, 6, 7*).

Figure 2 may also be used to estimate the specific impulse obtainable from hydrogen gas heated by an external energy source, for example, a nuclear reactor or an electric arc. To do this it is simply necessary to locate on the lowest line of the chart, the temperature to which materials' limitations allow us to heat the hydrogen, to run a vertical line from this point to the I_{sp} (upper) curves, and then horizontally to the left to read the corresponding I_{sp}. The splitting of the upper curves labeled "shifting" and "frozen" refer, respectively, to the nozzle expansion iterative calculation with and without allowing the chemical composition of the exhaust to equilibrate instantaneously, according to changing temperature and pressure conditions encountered during expansion from the initial equilibrium condition.

It should be stated that in the course of very extensive, vigorous, and well-supported experimental research programs, the highest concentrations of free radicals which have been stabilized are well below 1%. Bearing in mind that an arrested free radical fuel system will require considerable equipment for its stabilization (it is a monopropellant whose utilization will be most difficult), we may say that, at this time at least, free radicals do not show promise as the solution to our propellant limitation problems (*5*).

Table 2 indicates some high specific energy contents for ions. These are equivalent to theoretical I_{sp}'s ranging up to 4500 "seconds". Suffice it to say that, thanks to the ubiquitous electron, the isolation and stabilization of usefully high spatial concentrations of ions do not appear likely.

Table 2. Energy content of nonredox systems.

Parent species	Radical	Energy of dissociation, kcal/g. mole of parent species	ΔH_c, Energy of dissociation kcal./g.
H_2	H	103.24	51.21
O_2	O	117.17	3.66
N_2	N	224.90	8.03
C_2H_6	CH_3	83.317	2.77
NH_3	N, H	277.	16.26
F_2	F	35.6	0.94
CH_4	C, H	363.5	22.66
CH_4	CH_3, H	101.	6.30
H_2O	H, OH	118.	6.55
NH_3	NH_2, H	102.	5.99
Ne	Ne•	380.	18.83
He	He•	453.	113.17
He	He^{++}	1821.48	455.03
H	H^+	365.138	362.24
He	He^+	566.86	141.61
Ne	Ne^{++}	1444.35	71.56
Be	Be^+	293.049	32.51
B	B^+	287.32	26.55
A	A^{++}	1000.28	25.04
Ne	Ne^+	497.19	24.63
O	O^+	372.555	23.29
Li	Li^+	160.799	23.17
$H_2 + 0_2$ (Stoich.)		57.8	3.2
JP-4 + 0_2 (Stoich.)		....	2.4

George C. Szego is on the technical staff, Space Technology Laboratories. His current work is on reconnaissance satellite weapon systems and their ancillary sub-systems. Szego was formerly in GE's Flight Propulsion Division. He also headed the Chemical Engineering Department at Seattle University for eight years. A consulting editor of Astronautics Magazine, he has published several papers and co-authored a book, Free Radicals as High Energy Propellants. Holder of several patents, Szego is on A.I.Ch.E.'s National Program Committee.

Quite different considerations apply to the metastable states of the noble gases. The energy storage in these is effected by electronic excitation to orbitals higher than the ground state. In principle, incident quanta cause one of the electrons (say in helium) to absorb energy and "jump" to an excited state: ^1S or ^3S orbitals. Quantum mechanical selection rules, statistical rather than absolute in nature, "forbid" direct return to the ground state by mere energy emission. Thus, the excited atom must first pass to a higher energy state, whence it may then drop to the ground state directly. This creates a situation exactly analogous to the activation energy of a chemical reaction and confers a

quasistability in the excited state, which is thus known as "metastable".

The theoretical performance capabilities of metastable helium are shown in Figure 3. At very low concentrations this very energetic substance is capable (in principle) of exceeding the performance of the best chemical propellants. Various workers have estimated the half life of the metastable state at low temperature (*8, 9, 10, 11*). These are of the order of a few hours.

The results of a simplified quantum mechanical calculation of the half life of metastable neon at 300 lb./sq. in. abs. are indicated in Figure 4. It is seen that at low temperature (6-7°K) the half life may approach useful values. The half life of metastable helium should be longer.

Another aspect of nonredox systems as advanced energy sources lies in the possible utilization of the steady-state concentrations of free radicals in the upper atmosphere due to solar radiation absorption. Recent studies (*12, 13*), indicate that despite a total of about 53 mol. % of radicals (O and N at about 460,000 feet elevation; the energy density is only about 3.0×10^{-6} Btu./cu. ft., $\pm 2 \times 10^{-6}$ Btu./cu. ft.). Estimates of the drag upon a hypothetical free radical ramjet vehicle indicate that this figure is about 3×10^{-6} Btu./cu. ft. Hence, the only possibilities lie in a clarification of the exact properties of the ionosphere and the means of effecting efficient and volumetric recombination within the vehicle. Calculations at other elevations indicate that the energy available is less than that consumed by drag.

In summary, free radicals and similar nonredox systems represent a theoretical possibility for the storage of energy in sufficient density to outperform chemical propellants for rocket propulsion. Feasibility has not yet been established for such systems, but dissociated molecules have not been stabilized in sufficient quantity to appear as attractive prospects. Metastable inert gases require experimental verification of their half lives to establish bases for further evaluation.

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Status of free radicals

J. L. FRANKLIN

A survey of the broad-front investigations into methods of isolating free radicals and the prospects for their practical application.

RECENT STUDIES BY RICE (*1, 2*) and Broida (*3, 4*) have suggested that active free radicals might be stabilized and preserved by entrapment in a solid matrix. Although the chemistry of radicals in gases (*5*) and liquids (*6*) has been the subject of many investigations, only in recent years has attention been directed toward radicals in solids.

Free radicals, since they have unpaired electrons, have paramagnetic properties. In recent years paramagnetic, or electron spin resonance, properties of radicals have been studied extensively with a view to using such information to elucidate questions of structure and as an analytical device for determining radical concentration (*7, 8, 9*). Electron spin resonance measurements have been made in the gas phase on such stable free radicals as O_2 (*10, 11*), NO (*12*), and NO_2 (*12*), and on such highly active entities as H(*13*), N(*14*), and O(*15*) atoms which can be generated in fairly high concentrations in the gas phase. Unfortunately, more complex radicals are difficult, if not impossible, to generate in large concentrations in the gas phase, and so measurements of the magnetic properties of gaseous radicals have been limited to these few atomic species.

The problem, then, in studying free radicals is to obtain them in sufficient concentration and at the same time to isolate them from other radicals for a sufficiently long time to permit control and examination. The early studies of Broida (*3, 4*) and his colleagues suggested how this might be done. In their work they generated an afterglow by passing nitrogen through a discharge and then passing the flowing gas over a surface cooled to 4°K. The gas condensed to a solid which glowed with a brilliant green color. The glow disappeared a few seconds after the electric discharge was discontinued but reappeared upon warming and persisted, with some changes in color, until a temperature of the order of 30 to 35°K was reached. The emission of light and the occasional violent explosions were ample evidence that highly energetic species were present, and the most reasonable interpretation of the results was to attribute this activity principally to nitrogen atoms trapped in the solid. Although this view had to be modified in detail as a result of subsequent studies, it is still essentially the correct one. Stemming from these observations, a great deal of research on the trapping of radicals in solids has been and is being conducted. Broadly, research on trapped radicals

has tried to answer the questions how to generate trapped radicals, how to identify the active species present, how to measure their concentration, and how to recover them from the solid. None of these questions has been completely answered at this time.

Generation of trapped radicals

In general, trapped radicals can be prepared in two ways: by generating the radicals in the gas phase and suddenly freezing them in a solid matrix at low temperatures or; by irradiating the appropriate solid with either ultraviolet light or ionizing radiation. Both methods have been used extensively. The generation of radicals in the gas phase has usually (and more successfully) been done by electric discharge although both photolysis and pyrolysis of the gases have been employed. Both methods give similar results although each presents problems. When an activated gas is condensed, even at very low temperature, it is almost impossible to remove the energy from the gas completely at each collision of a gas molecule with the wall. The result is that the radicals strike the wall many times before being trapped in the solid, and a large number of them will be removed by chemical reaction. Further, diffusion may occur within the matrix or on the surface with resulting loss of radicals by recombination.

Radicals are usually formed by breaking chemical bonds, and thus they will normally be formed in pairs. If the radicals are formed by irradiation or photolysis of a solid, they will be trapped in pairs in a cage and will recombine immediately. It is only when there is an opportunity for diffusion so that some radicals can escape from the cage, but without enough energy to reach a second radical, that radiation can successfully produce stabilized radicals. In both methods, wherever two radicals recombine a great deal of heat is liberated and the matrix in the neighborhood will be softened and melted. If other radicals are close by, they will have an opportunity to diffuse together and react. In this way an energy chain can be initiated causing the entire system to react very rapidly. Thus, as will be discussed later, the problem of trapping radicals in high concentrations is a very difficult one and has not yet been solved.

Identification

The identification of trapped radicals presents many serious problems, and, as a consequence, only a few have been convincingly identified. The difficulties are obvious. First, one can never be certain that only one active species is present and, in fact, one can imagine few systems where this would be true. Second, almost no data exist on the effect of the crystal field upon the radical trapped in it. The principal means of identifying radicals trapped in solids have been emission, infrared absorption, and electron spin resonance spectra. Chemical evidence has also been employed, but not always successfully.

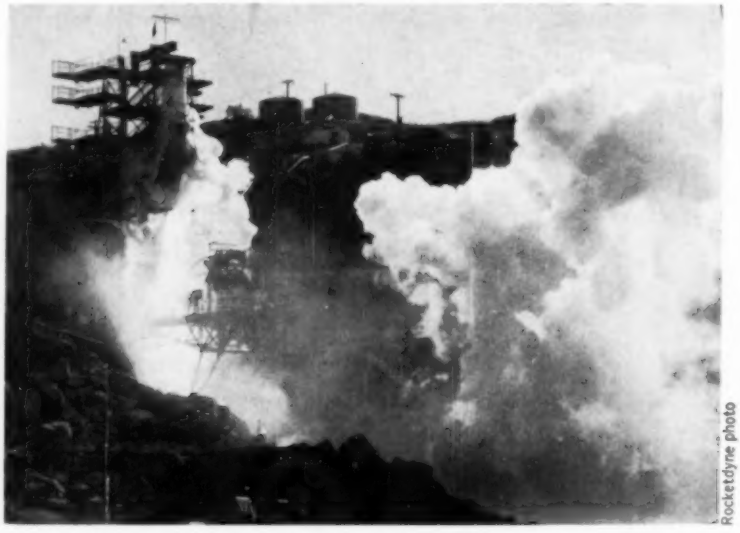
The free radical systems that have been subjected to the most extensive investigations have been hydrogen, nitrogen, oxygen, NH, and methyl. When hydrogen gas containing H atoms is condensed at 4°K only a very weak glow is observed in the gas near the solid and none in the solid itself (*16*). No absorption bands can be detected in the near infrared. Thus, there is no spectral evidence for trapped H atoms. H atoms have been trapped in very low concentration in a hydrogen lattice and have been positively identified by Jen *et al.* (*17, 18*) using electron spin resonance. Hydrogen atoms gave a typical doublet and deuterium a triplet, similar to the spectra obtained in the gas phase. There has also been considerable speculation as to whether the hydrogen and deuterium atoms were trapped as H_3 or D_3. Some electron spin resonance data (*18*) suggest this possibility but are inconclusive. Attempts to predict the spectrum of H_3 from *a priori* theoretical considerations have also been inconclusive (*19*).

Some interesting measurements have been made by Livingston (*20, 21*) and by Matheson and Smaller (*22*). Livingston irradiated solidified aqueous solutions of several acids with gamma rays from cobalt-60 at 77°K, and Matheson and Smaller performed similar experiments with ice. Both groups measured the electron spin resonance of the irradiated solid and found spectra characteristic of hydrogen atoms, Table 1. The measurements on ice, however, gave line separations much smaller than those in the gas phase or in the acid-water mixture. The discrepancy has not been satisfactorily explained.

Table 1. Identification of trapped hydrogen atoms.

Radical	Matrix	T°K	Method
H, D	H_2	4	esr
H	Ice ?	77	esr
H, D	H_2O-H_2SO_4	77	esr
H	CH_4	4	esr

Nitrogen atoms have undoubtedly been the most intensively investigated of any trapped radical. Unfortunately, some of the published material is conflicting, and final explanations of most of the phenomena have not as yet been adduced. The principal energetic species present in the nitrogen afterglow is atomic nitrogen in the ground (^4S) state (*23*), and in most of the studies discussed here the N atom concentration is in the order of 2% (*23, 24, 25*). However, small amounts of nitrogen in both the ^2D and ^2P states are present (*26*), their concentrations being, perhaps, 1% of that of the ground state N. The principal spectrum observed in the nitrogen afterglow is due to the $B^3\Pi_g \longrightarrow A^3\Sigma_u^+$ transition of molecular nitrogen which in turn arises somewhat



Rocketdyne photo

Remote at present, free radicals may yet be used for future propulsion.

indirectly from the recombination of nitrogen atoms.

When the glowing nitrogen gas is condensed at liquid helium temperature, the principal emission spectrum arises from ^2D–^4S transition of atomic nitrogen although many other bands are observed (*4*). The ^2P–^2D transition of atomic nitrogen has been found in the near infrared emission spectrum (*27*). It is interesting that the $B^3\Pi_g$———$A^3\Sigma^+u$ transition which dominates the gas phase afterglow is not observed. Unfortunately, impurities account for much of the spectrum observed, and several false starts toward interpretation of the results are attributable to this fact. Thus, one of the principal sets of bands originally attributed to one of the nitrogen transitions was later definitely proved to be due to the $^1S_0$–$^1D_2$ transition of atomic oxygen present as an impurity (*28*). It is significant that the emission spectra of trapped N and O were shifted slightly toward lower energies, suggesting some kind of stabilizing interaction with the solid lattice. Milligan *et al.* (*29*) obtained infrared absorption spectra on the glowing solid and attributed certain bands to the radical, N_3. However, both energy and spin orbital correlation considerations cast some doubt upon N_3 as an important method of stabilizing N atoms. Thus, we have no spectral observations on the most important free radical species presumably present in the solid—namely N^4S—and must rely on other methods for its detection.

Perhaps the most positive identification of trapped nitrogen atoms has been made by electron spin resonance. Both Cole *et al.* (*30*) and Foner *et al.* (*31*) measured the electron spin resonance spectrum of the condensed nitrogen afterglow, Table 2. Both obtained a triplet similar to that of N^4S in the gas. Foner *et al.* also studied the effect of hydrogen and methane as the trapping matrix and found a small shift in the hyperfine splitting, the shift increasing as the binding strength of the matrix increased. All of the investigators found satellite lines which have not yet been satisfactorily explained.

Oxygen atoms, NH, NH_2, HO_2, and OH radicals have been the subject for numerous investigations, but unfortunately the evidence bearing on all of them is incomplete. Thus, as was mentioned above, O atoms have been found as impurities in the glowing nitrogen solid but as yet they have not been identified in oxygen that has been condensed after passing through a discharge. Ozone is evolved in copious quantities when the solid is warmed (*32, 33*), indicating that O atoms were present at some time but there is no convincing evidence that they are trapped in the solid. The NH radical has been tentatively proposed (*1, 2*) to explain the blue color of the solid obtained when hydrazoic acid vapors are partially decomposed and immediately condensed at 77°K. However, its presence has not yet been proved although it now seems definite that, at most, it can be present only in small concentrations (*34, 35*). However, Robinson and McCarty (*36*) have detected both NH and NH_2 by the absorption spectra of the products of a discharge through hydrazine and argon condensed at 4°K. The OH and, especially, the HO_2 radicals have been sought as explanations for the behavior of the solid obtained by freezing the gases leaving an electric discharge in water vapor or hydrogen-oxygen mixtures. Electron spin resonance data on such solids (*37*) might be attributed to OH or HO_2, but the assignment is not definite and the data do not agree with electron spin resonance measurements on gamma-irradiated ice (*22, 38*) which have also been attributed to these radicals. Iodine atoms, CS, ClO, and benzyl have been trapped in hydrocarbon glasses irradiated with ultraviolet light at 77°K, and their presence identified spectroscopically, Table 3 (*39, 40*).

Several studies have been made in an effort to trap and identify organic radicals in various matrices. Unfortunately, few of these are completely convincing and, in fact, the only satisfactory studies have been of the methyl and benzyl radicals. In all cases except benzyl, attempts at identification have consisted of measurement of the electron spin resonance spectrum of a solid at low temperatures. In most instances the solid is first irradiated with gamma rays to bring about dissociation and the formation of radicals.

When protons are present in a free radical, they will couple or resonate with the spin of the unpaired electron. If all of the protons couple equally, the spectrum will show one line more than the total number of protons in the radical. Thus, the spectrum of hydrogen atoms is a doublet and of methyl, a quartet. With equal coupling the relative intensities of the lines are also predictable, the ratios being those of the coefficients of the binomial expansion to the power of the number of protons involved. These considerations form the basis for most of the identifications of organic free radicals entrapped in various matrices. Thus, Gordy and McCormick (*41*) found a quartet in the electron spin resonance spectrum of zinc dimethyl irradiated with x-rays at 77°K. Smaller and Matheson (*42*) and Wall *et al.* (*43*) irradiated solid methane with gamma rays and found a quartet with intensities of the expected order, namely in the ratio 1:3:3:1. Jen *et al.* (*18*) passed methane through a mild discharge and trapped the products at 4°K. They similarly irradiated methyl iodide with ultraviolet at 4°K. In both cases they obtained a quartet in the electron spin resonance spectrum. The data thus show rather conclusively a methyl radical as the species trapped, Table 4.

Several investigators have studied more complex systems and have attributed the resulting spectra to various possible individual free radicals. Thus, Gordy and McCormick (*41*) obtained a symmetrical sextet from irradiated mercury diethyl which they attributed to the ethyl radical. Smaller and Matheson (*42*) obtained a quartet of triplets on irradiation of ethane, ethylene, and ethyl chloride at low temperatures, and decided that their results were similar to those of Gordy and McCormick, except that the latters' spectra involved line broadening due to the influence of the matrix. They also attributed their spectrum to the ethyl radical. It is not clear why other radicals would not also be formed in a system of this kind. Smaller and Matheson (*42*) have irradiated several hydrocarbons in this way and Luck and Gordy (*44*) have irradiated various alcohols, amines, and mercaptans. In each case, the spin resonance spectra were attributed

Table 2. Identification of trapped nitrogen atoms.

State	Matrix	T°K	Method
^4S	H_2, N_2, CH_4	4	esr
^2D	N_2	4	emission spectra
^2P	N_2	4	emission spectra

Table 3. Identification of various trapped inorganic radicals.

Radical	Matrix	T°K	Method
O	N_2	4	emission spectra
I	glass	77	absorption spectra
ClO	glass	77	absorption spectra
N_3(?)	N_2	20	absorption spectra
NH	A	4	absorption spectra
NH_2	A	4	absorption spectra

to a single free radical. Gibson *et al.* (*45*) and Ingram and Symons (*46*) have irradiated several alcohols fixed in a water-H_2O_2 glass with 2537 Å mercury radiation. Apparently the hydrogen peroxide was decomposed to OH radicals which then abstracted hydrogen from the alcohol leaving a free radical which was identified by its spin resonance spectrum.

Concentration in the matrix

It is evident from the above that the problem of identifying trapped free radicals with certainty is a complex one which has been solved satisfactorily in only a very limited number of cases. The problem of determining the number or concentration of trapped radicals is even more difficult since it involves not only identification, but measurement of the numbers involved. The most satisfactory methods for measuring concentration have been magnetic, employing either spin resonance or magnetic susceptibility. In his studies of hydrogen atoms, Livingston (*47*) estimated the hydrogen atom content of the irradiated frozen aqueous solutions of acids to be in the order of 0.1%. He also collected the hydrogen evolved upon warming the mixture and got satisfactory agreement with the spin resonance measurements. Matheson and Smaller (*22*) estimated the hydrogen atom content of irradiated ice to be of the order of 0.05 mole %, and from dipolar broadening, Jen *et al.* (*18*) estimated that the hydrogen atom content of the lattice was about 0.01%. In neither case were efforts made to maximize the hydrogen atom content and so the results given are not necessarily limiting.

Perhaps the most convincing measurement of the concentration of nitrogen atoms in a solid deposited from the nitrogen afterglow has been made by Fontana (*48*) who measured the magnetic susceptibility of the solid during deposition. He found that the nitrogen atom content built up slowly to concentrations as high as about 0.5%. Near this concentration the situation became unstable and a characteristic yellow flash occurred, at which point the temperature rose and the nitrogen atom content dropped precipitously. The atom content would then slowly build up until the unstable situation was again reached. Wall *et al.* (*43*) have estimated the nitrogen atom content of gamma irradiated solid nitrogen to be about 0.1%. Other, and much less reliable methods, have led to values as high as 4 to 6% (*49*). However, these higher values came from measurements of total heat release. Because this heat might have come from excited molecular species, the analysis should be taken with serious reservations.

Estimates of oxygen atom content in the solid condensed after passing oxygen through an electric discharge have led to values as high as 11%. It must be emphasized, however, that oxygen atoms have never been positively identified in the solid and the methods used for estimating their concentration are indirect and extremely doubtful. Thus, calorimetric methods (*49*) lead to oxygen atom contents of the order of 6%, and interpretations based upon the formation of ozone (*33*) have led to values in the order of 11%. The calorimetric method is questionable because of the possibility that the heat released came from sources other than atomic oxygen, and the high value of 11% obtained by inference from chemical reaction is probably of no value since infrared spectra have shown that no change in ozone content occurred during warm-up of the solid (*50*).

Wall *et al.* (*43*) found both methyl radicals and hydrogen atoms upon irradiating methane with gamma rays from cobalt-60 at 4°K. The total radical content of the solid was estimated, by electron spin resonance methods, to be of the order of 0.08%. Upon warming, the hydrogen atoms disappeared more quickly than the methyl.

From the above it is evident that the best data uniformly point to very low free radical contents. This is especially disappointing to those interested in the use of trapped radicals as jet fuels. It should not be surprising since it is necessary that the radicals be separated by a rigid matrix if they are to be prevented from recombining and since any recombination is probably sufficient to set off a chain reaction, resulting in the disappearance of essentially all of the radicals. Statistical studies have been made by Jackson and Montroll (*51*) and Golden (*52*) in an effort to ascertain the probability of laying down an array of radicals on sites that would be sufficiently isolated from other radicals to be stable. The results have shown a maximum of about 10-15% radicals in the solid. A more sophisticated treatment by Jackson (*53*), employing a model based on autoignition, has deduced a maximum nitrogen atom content of about 0.3%, in good agreement with the value obtained experimentally by Fontana (*48*). Thus, it seems doubtful at this time that there are any reasonable prospects of obtaining high concentrations of radicals in the near future.

J. L. Franklin was appointed to the post of research associate at Humble Oil & Refining when it was established in 1947. He recently spent eighteen months with NBS, as guest scientist on the free radicals project. Franklin has published in the fields of reaction kinetics, thermodynamics and electron impact phenomena. He is now on the advisory board for a new series of reference books on Advances in Petroleum Chemistry and Refining. A member of the Farady Society, ASTM, and a fellow in the Physical Society, he is also a former chairman of A.I.Ch.E.'s South Texas Section.

The effect of matrix material upon the stabilization of radicals has not been established although there have been small advances made in this field. In general, the higher the melting point, or the higher the energy of vaporization of the matrix material, the more effective is the matrix in stabilizing radicals. This was indicated above in the effect of hydrogen, nitrogen, and methane on the hyperfine splitting of nitrogen atoms (*17*, *18*). It has also been observed by Pimentel and his colleagues (*54*, *55*) who found that stabilization increases in the order nitrogen, argon, krypton, and xenon as would be expected from their melting points and heats of vaporization. However, there are essentially no data on the stabilization of radicals in strongly-bound matrices such as might be expected of water. An exception has been noted in the studies of irradiation of ice and aqueous solutions of acids at 77°K, where small concentrations of hydrogen atoms were trapped. It is interesting that in Wall's studies of irradiation of methane, the hydrogen atoms disappeared at temperatures far below 77°K. Glasses have been used in several studies and have been found to be effective in trapping radicals, but no systematic study of their effectiveness has been made. It is evident that much work still needs to be done to define the effect and mode of action of the matrix in trapping radicals.

Recovery of trapped radicals. Very little has been done to develop methods of recovering radicals from a matrix. In fact, the author knows of only one brief paper on this subject. Broida and Peyron (*56*) collected the glowing nitrogen solid at 20°K then let the solid warm slightly and distill to an adjacent surface at about 1.2°K. The redistilled solid, collected at the lower temperature, showed the characteristic spectral lines of the ^2D-

^4S transition of nitrogen atoms, thus indicating that nitrogen atoms can be vaporized from a solid and recondensed. The second solid also exhibited a faint glow indicating that other active species were probably transferred also.

Chemical Reactions

A few studies of chemical reactions of trapped radicals (other than simple recombinations) have been made. Klein and Scheer (*57, 58*) have studied the chemical reactions occurring when H or D atoms from the gas phase impinge upon and diffuse into thin layers of solid olefins at 77°K. With propylene and 1-butene they found that the atom added to the terminal carbon yielding a secondary radical which could then add a second H atom, dimerize, or disproportionate. Both the structure and molecular weight of the olefin affected the results significantly.

Using the matrix isolation technique, Pimentel (*59*) has studied the cis-trans isomerization of HNO_2 at 20°K, and at the same conditions Brown and Pimentel (*60*) studied the photolysis of nitromethane and methyl nitrate. They concluded that the nitromethane isomerized to methyl nitrite which then decomposed giving formaldehyde and HNO_2 as principal products.

It was mentioned earlier that oxygen gas containing O atoms produces ozone in large yields at low temperatures, although it is not certain that this reaction occurs in the solid phase. Similarly, water vapor or hydrogen-oxygen mixtures when passed through a discharge and condensed at 77°K produce considerable amounts of hydrogen peroxide, but we are not certain that the reaction occurs in the solid. It is evident, however, that at very low temperatures only those reactions which involve very low activation energies can occur at significant rates. Thus, the techniques of carrying out chemical reactions at very low temperatures offer an opportunity, in some instances, to obtain very high selectivities with low yields of undesirable by-products. But, much remains to be done before practical applications can be expected.

Table 4. Identification of some trapped organic radicals.

Radical	Matrix	T°K
$\dot{C}H_3$	$Zn(CH_3)_2$	77
$\dot{C}H_3$	CH_4	4
$\dot{C}H_2OH$	glass	77
$(CH_3)_2\dot{C}OH$	glass	77
$CH_2 = CH\text{-}\dot{C}HOH$	glass	77

Table 5. Concentration of trapped radicals.

Radical	Matrix	T°K	Concentration, %
H, D	H_2	4	0.01
	CH_4	4	0.05
	H_2O	77	0.05
	$H_2O\text{-}H_2SO_4$	77	0.10
N	N_2	4	0.1
	N_2	4	0.5
	N_2	4	6.0
CH_3	CH_4	4	0.032

Practical applications

The advantage of using free radicals as rocket fuel arises from the possibility of obtaining high thrust. Thrust depends primarily upon the energy release per unit of mass and consideration of the various radicals that might be used reveals that only hydrogen atoms or helium in the triplet (or higher) excited state would have any large thrust advantage over more conventional fuels. The very low concentrations of trapped radicals obtained to date make this application very remote although, of course, some unexpected discovery might improve the prospects.

If trapped radicals are ever considered for commercial chemical process applications, several problems will demand serious consideration. Among the most serious of these are the very low temperatures involved and the accompanying problems of heat economy. Most of the successful trapping of radicals so far has been at 4–20°K, a temperature very difficult and expensive to achieve. The trapping agents employed have been characterized by rather weak matrix binding forces. In a few instances radicals have been stabilized at higher temperatures (77-125°K) in ice or certain glasses. It seems probable then, that by proper choice of matrix, higher, and hence more economic, temperatures can be employed. No serious study of this problem has been made, however, and a systematic investigation would seem to be both desirable and necessary if any commercial application is to be achieved.

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Ernest E. Donath and Martin Hess

Thermally stable hydrocarbon fuels

Photo courtesy Republic Aviation Corp.

The supersonic F-105 Thunderchief shown here climbing vertically through the sun's rays is a potential user of proposed fuels.

Hydrocarbon fuels break through the thermal stability barrier. Test results show saturated cyclic hydrocarbons to be suitable jet and missile fuels.

Saturated cyclic hydrocarbons with one or two rings show the greatest promise for use as thermally stable fuels in jets and missiles flying at speeds of several Mach numbers. These hydrocarbons may also be suitable as engine coolants. This article is a survey of available likely hydrocarbon fuels and their costs.

Evaluation of potential fuels

High temperature fuels must meet the following requirements set forth at Wright Air Development Center *(1)*:

1. Good thermal stability.
2. Good combustion characteristics.
3. Close definition of properties.
4. The best low temperature properties commensurate with items 1 through 3.
5. Heating value as high as possible. A minimum heating value of 18,400 B.t.u./lb. has been established.

The potentially suitable hydrocarbon classes were selected on the basis of these requirements and of Wright Field's CFR-fuel coker tests. A synopsis of this selective process follows:

Olefins and acetylenes can be excluded immediately because of their high reactivity and lack of stability. The remaining hydrocarbons can be arranged in a plot showing their net heating value vs. the number of carbon atoms per molecule, Figure 1. Using the minimum net heating value of 18,400 Btu./lb. as a criterion, aromatic hydrocarbons are excluded. This is actually not a new limitation since the combustion characteristics of aromatics are stated to be unsatisfactory *(1)*. Even present jet fuel specifications exclude aromatics or limit the permissible aromatics content. The remaining hydrocarbon classes are the paraffins and saturated ring derivatives.

Data which indicate that aliphatic petroleum fractions have lower thermal stability than pure saturated cyclic hydrocarbons were presented at the WADC Fuels Meetings. It may be possible to obtain petroleum fractions that have satisfactory properties as supersonic fuels, but this may require selection of crudes, or of specific fractions, and special refining methods. However, consideration of such fuels is not within the scope of this article, which is concerned exclusively with fuels consisting of saturated cyclic hydrocarbons.

On the basis of bond energies, the net heat of combustion H_c of saturated hydrocarbons can be correlated in terms of the number of carbon atoms n and the number of rings r.

$$H_c = 18{,}738 \frac{7 - 2.25\,\frac{r-1}{n}}{7 - \frac{r-1}{n}} \text{ B.t.u./lb.} \qquad (1)$$

The condition for a jet fuel is

$$H_c \geq 18{,}400 \text{ B.t.u./lb.} \qquad (2)$$

By combining Equations 1 and 2 one obtains the condition:

$$r \leq 1 + 0.10\,n \qquad (3)$$

Eq. 3 imposes an upper limit on the permissible number of rings for a

Table 1. Properties of selected cyclic fuels (*1, 2, 3, 4*).

Compound	Sp. gr. $\frac{20}{4}$	Net heat of comb. Btu./lb.	Net heat of comb. Btu./gal.	Freezing point, °F	Boiling point, °F
1. diethylcyclohexane	0.802	18,560	124,000	<−74	340
2. 2-methylbicyclohexyl[a]	0.884	18,500	136,600	−16	482
" [b]	0.895	18,650	139,000	+14	491
3. 2-isopropylbicyclohexyl[a]	0.904	18,700	141,000	16	542
" [b]	0.893	18,500	137,600	Glass	531
4. bicyclohexylmethane	0.876	18,425	134,500	−2	487
5. 1, 4-bicyclohexylbutane	0.870	18,500	134,100	60	588
6. decalin (cis)	0.896	18,370	137,800	−45	384
(trans)	0.870	18,320	133,000	−23	370
7. 2-ethyldecalin	0.883	18,414	135,700	−96	505
8. 2-*n*-octyldecalin	0.907	18,464	139,700	−54	617
9. hydrogenated creosote	0.893	18,320	136,000	<−76	338–525

[a] *low boiling isomer.*
[b] *high boiling isomer.*

given number of carbon atoms and thus is useful in selecting compounds having a satisfactory heating value. In the approximate boiling range of jet fuels, that is for compounds with less than 20 carbon atoms per molecule, saturated polycyclics with three or more rings have a heating value below 18,400 B.t.u./lb. and thus cannot be predominant components of jet fuels. This leaves only cyclic compounds with one and two rings.

The properties of some saturated cyclic compounds are shown in Table 1. The first compound, diethylcyclohexane, has a satisfactory heating value and freezing point. Its specific gravity and heating value per gallon are also similar to those of commercial jet fuels. Its boiling point may be too low for some applications.

The remaining compounds shown in Table 1 are bicyclics of various types. As a class, these bicyclics have higher specific gravities (0.87–0.91) than normal jet fuels. Consequently, their heating value per gallon (about 135,000–141,000 B.t.u.) is considerably higher than that of present jet fuels (about 120,000–125,000 B.t.u./gal.). This property may be of interest in high speed aircraft.

Within the polycyclic group the specific gravity is higher for compounds with directly linked or condensed rings, such as bicyclohexyl or decalin, than for compounds whose rings are separated by one or more carbon atoms. Decalin and its homologs exhibit the lowest freezing points, whereas the freezing points of the other bicyclics are not satisfactory. Data available to the authors are not sufficient to indicate conclusively which mixtures of homologs and isomers of this type have satisfactory low temperature properties. However, a fuel obtained from creosote fractions by hydrogenation had satisfactory low temperature properties.

The creosote oil fraction used as raw material was purely aromatic and contained naphthalene homologs as major constituents. The thermal stability and combustion properties of the hydrogenated oil were determined at Wright Field in a CFR-coker. At a preheater and filter temperature of 450 and 500°F, respectively, the pressure drop was very low, 4.1 in. after 300 min.; however, the preheater tube deposit appeared marginal. The heating value of this fuel is just below 18,400 Btu./lb.

The importance of a close definition of properties has been mentioned. Present specifications establish limits for specific gravity, boiling range, freezing point, heating value, etc., to characterize a fuel. If this should be insufficient, and if the closer definition inherent in the use of a pure chemical should be required, a relaxation of other specifications, for instance those related to low temperature properties, may be necessary. With present specifications, decalin

Table 2. Typical raw material prices (as of Jan. 1959).

Basic raw materials	Cents/lb.	Cents/gal.
creosote oil	2.3	20
toluene	3.5	25
xylene	4.0	29
benzene	4.2	31
methylnaphthalene	(6.2)[a]	(54)[a]
naphthalene (crude)	6.2	(54)[a]
Other raw materials		
ethylene	5.0	(35)[a]
hydrogen	11	($0.60/MCF)[a]

[a] *Bracketed figures are approximate.*

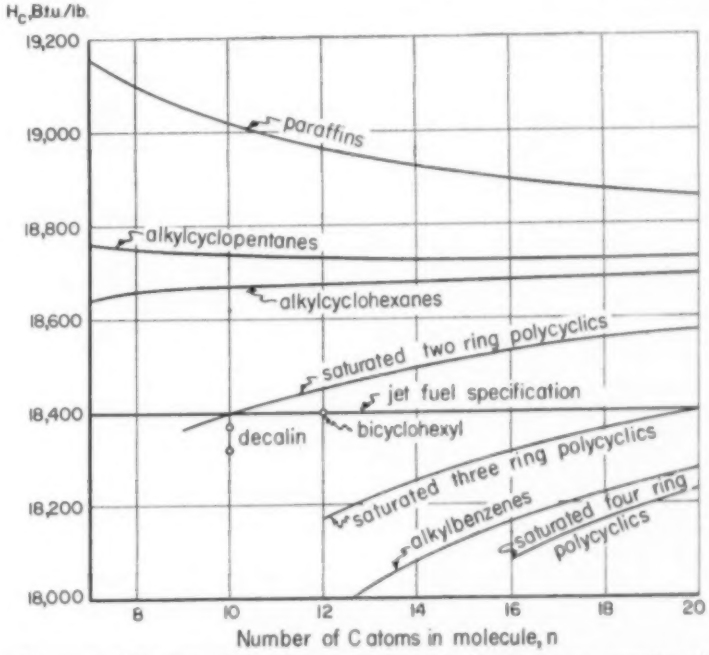

Figure 1. Net heats of combustion of liquid hydrocarbons vs. number of carbon atoms in the molecule.

North American Aviation

Battling the thermal barrier, the Air Force's X-15 is shown in its first successfully completed powered flight. It rose to 50,000 feet.

homologs appear to be the only compounds that are suitable in the pure state.

This review may be summarized by stating that several mono- or bicyclic compounds, or mixtures thereof, should be suitable as high temperature fuels. Attention can now be focused on how to obtain these compounds.

Raw materials and manufacture

The thermally stable fuels considered here are all derived from various aromatic hydrocarbons, Figure 2. Benzene, toluene, and xylene are the raw materials for cyclohexane homologs and noncondensed bicyclics. A cyclohexane homolog such as diethylcyclohexane is produced by alkylation of benzene with ethylene, followed by hydrogenation. Both reactions are being used on a commercial scale. Other cyclohexane homologs could be obtained by the alkylation of toluene and xylene with higher olefins such as propylene, butylene, etc.

Additional processing steps are required for the production of noncondensed bicyclics. Diphenyl is produced commercially from benzene. Its alkylation and hydrogenation lead to alkylbicyclohexyls. Dicyclohexylalkanes can be obtained by various combinations of alkylation and hydrogenation reactions.

Alkylation of naphthalene followed by hydrogenation yields alkyl decalin fuels which could also be obtained by the direct hydrogenation of naphthalene homologs. The alkylation of naphthalene is carried out commercially as is the hydrogenation of naphthalene to decalin. Hydrogenation of creosote oil fractions leads to similar products. It is also possible to alkylate creosote oil fractions prior to hydrogenation. The sidechains thus added to the creosote increase its heating value per pound.

The basic processes for the preparation of all these cyclic fuels are known and long-term development work would not be required. Some experimental work would be needed in most cases for the design of commercial plants to define the most advantageous operating conditions.

Table 3. Raw material costs unit product.

Compound	Unit process steps	Raw materials	Raw material cost per unit of product cents/lb.	cents/gal.
methylisopropyl cyclohexane	2	toluene, propylene, hydrogen	4.2	28
diethylcyclohexane	2	benzene, ethylene, hydrogen	4.8	32
propylbicyclohexyl	3	benzene, propylene, hydrogen	4.6	34
bicyclohexylbutane	4	benzene, ethylene, hydrogen	4.8	35
ethyldecalin	2	naphthalene, ethylene, hydrogen	6.3	46
alkylated, hydrogenated creosote	2	creosote oil, ethylene, hydrogen	3.2	24

Cost

Having established the main raw materials for thermally stable fuels, two basic logistics questions of such fuels, namely their cost and available, or potentially available, quantities can be discussed. It is obvious that accurate figures for both can be obtained only when a final selection of a specific fuel and of the amount required has been made. However, at this stage estimates and "order of magnitude" figures will be useful. Typical raw material prices are shown in Ta-

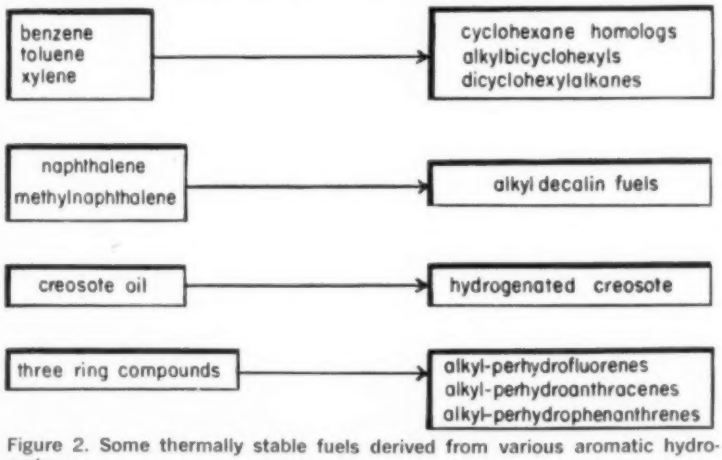

Figure 2. Some thermally stable fuels derived from various aromatic hydrocarbons.

Table 4. Benzene, Toluene, Xylene (5, 6, 7).
(all figures in MM gal./yr.)

Production	Benzene	Toluene	Xylene	Total
1957 from coal	192	39	11	242
1957 from petroleum	110	161	129	400
1957 Total	302	200	140	642
1960 estimated production				718
1975 estimated production				1371
Estimated production capacity of aromatics from petroleum				750
Catalytic reforming capacity of U. S. petroleum industry (1958)				21,300

ble 2. None of the raw materials is as low in cost as the present jet fuel. Table 3 shows the number of processing steps and the present cost of the raw materials per pound, and per gallon, of fuel assuming theoretical yield. Only a few examples are given but they are believed to be typical. The raw material costs alone are about 2½ to 5 times the cost of present jet fuel. To obtain the actual cost of the thermally stable fuels, this figure must be increased to account for operating costs, returns on investment, and actual yields. It thus appears that in large-scale production the cost of such fuels will be about 5 to 10 times that of present jet fuels. However, if a narrow fraction, or for example, only one of several isomers is used, the cost would increase because of higher processing cost and lower yield. On the basis of raw material cost and the number of processing steps, it seems that the lowest-priced thermally stable jet fuel would be:

1. a mixture of cyclohexane derivatives obtained by the alkylation of toluene, xylene, or mixtures of aromatics, followed by hydrogenation, or
2. alkylated and hydrogenated creosote oil.

Availability

It has been estimated (*1*) that the demand of high temperature fuels will approach 100 million gal./yr. (6500 bbl./day), a comparatively small volume in relation to the consumption of conventional jet fuels.

The raw materials required are monocyclic aromatics, condensed aromatics, gaseous olefins, and hydrogen. U.S. production of monocyclic aromatics, benzene, toluene, and xylene is shown in Table 4. These compounds, once a domain of coal and coke ovens, are produced in increasing amounts by catalytic reforming and extraction from petroleum fractions. Their 1957 production was 642 million gal. but the productive capacity was considerably greater. The production of these compounds is expected to grow and to roughly double by 1975 (*6*). Additional large amounts of aromatics are contained in catalytic reformates that are not being extracted to separate aromatics.

Donath

Hess

Martin Hess is a process engineer with Koppers' Research Department. A pioneer in application of statistical methods to organic synthesis, Hess spent several years in South America while with Parke Davis, working on start-up of synthetic organic chemical plants.

Ernest E. Donath is manager, planning section, Koppers. A Czechoslovakian, he came here in 1947 from Germany as scientific adviser to the War Department. He holds 100 patents for work on the DHD Process (German Hydroforming Process), and has authored several papers on coal hydrogenation and catalysis.

Table 5. Availability of polycyclic compounds in coal tar (5, 8).

Coke oven tar produced in 1956			833 MM gal.
Available coke oven tar			695 MM gal.
(Amount produced less steel mill fuel)			(6800 MM lb.)
This available coke oven tar contains:			
	% by wt.	MM lb.	MM gal.
naphthalene	10.9	750	(85)
methylnaphthalene	2.5	170	20
dimethylnaphthalene	3.4	230	24
acenaphthene	1.4	95	11
fluorene	1.6	110	12
anthracene	1.1	75	8
phenanthrene	4.0	270	(30)
Creosote oil (contains several of preceding compounds)			126

For condensed bicyclic and higher aromatics, coke oven tar is at present the main commercially available raw material, although naphthalene and its homologs can also be obtained from petroleum processing operations. Some streams from catalytic crackers and reformers contain naphthalene and its homologs. Aromatic extracts in the jet fuel boiling range are also available from kerosene. These, however, as indicated by their specific gravity and other physical data, contain only a minor portion of condensed bicyclics and consist mostly of substituted single ring aromatics and some nonaromatics.

Table 5 shows the coke oven tar produced in the U.S. in 1956 and the average amounts of various hydrocarbons contained in the tar. A large portion of the naphthalene is recovered as such. Methyl- and dimethylnaphthalene and higher boiling hydrocarbons remain in the creosote oil which is used mostly for wood preservation because of the stability and fungicidal and insecticidal properties of its constituents.

Gaseous olefins and hydrogen required for the alkylation and hydrogenation steps are expected to be available at a reasonable cost and in sufficient amounts.

Conclusion

On the basis of test results reported by WADC it seems that saturated cyclic hydrocarbons, especially bicyclics, obtained by hydrogenation of substituted aromatics will fulfill the requirements for thermally stable jet and missile fuels. The expected cost of such fuels will be about 5 to 10 times the price of present jet fuel. If future specifications should require pure chemical compounds rather than mixtures, higher costs should be anticipated. The raw material figures given in this paper indicate that it will be possible to meet the demand which is expected to approach 100 million gal./yr.

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DAVID S. PASTERNACK
Research Council of Alberta
University of Alberta

Petroleum substitutes from tar sands

Economical recovery of oil from the Athabasca tar sands, one of the world's major oil reserves, challenges man's ingenuity.

SYNTHETIC FUEL, SYNTHETIC OIL, and petroleum substitutes are terms which have been used often when describing the production of oil from coal by hydrogenation or gas synthesis, from oil shale by retorting, and from tar sands. When applied to tar sands the terms are misnomers, unless the qualification is made that they refer to oil obtained by means other than by conventional drilling.

The oil in tar sands, in its natural state, is a black viscous petroleum material with a consistency of molasses at room temperature. Because of its appearance, there has been a tendency to regard the oil as something different from crude oil, as evidenced by the terms "tar" and "bitumen" which have been applied to it. Actually, the difference is simply one of degree, and the tar sand oil falls at the heavy end of the crude oil series. Table 1 shows comparative data for Alberta tar sand oil and crude oils of Western Canada.

Due to the high viscosity of tar sand oil and the lack of a reservoir drive, normal crude oil production methods are of no avail. It so happens that the temperature of Alberta tar sand oil at some distance from the surface, is around 36 to 40°F. At this temperature the oil is so extremely viscous that it results in the tar sand being very firm and capable of supporting substantial structures. Yet when the tar sand at the face of a quarry is warmed by the summer sun, a small power shovel can dig into it readily until the warm surface layer is removed.

Geology

The Alberta tar sands comprise a portion of the McMurray formation, which is a Lower Cretaceous sediment resting unconformably on Devonian limestone and shale of Upper De-

Table 1. Comparative data for Alberta tar sand oil and crude oils of Western Canada.[1]

OIL FIELD	JOFFRE	PEMBINA	REDWATER	BANTRY	MARSDEN[2]	TAR SAND OIL
Geological age[3]	(L.C.)	(U.C.)	(D-3)	(L.C.)	(L.C.)	(L.C.)
Gravity, ° A.P.I.	41.3	36.8	35.4	22.8	13.9	9.5–6.5
Sulfur, wt. %	0.04	0.24	0.32	2.44	3.51	5.0
Viscosity, S.S.U. @ 100°F	38	46	43	172	5,330	–
Conradson carbon residue, wt. %	0.9	2.1	3.5	6.5	6.9	13–17
Total gasoline and naphtha, vol. %	31.8	28.0	29.2	16.6	–	–
Residuum, vol. %	25.4	30.1	28.0	44.3	56.9	63–75[4]
Well-head price, $/bbl.[5]	2.62	2.61	2.63	1.65	1.10	–

[1] *Data for all the crude oils, except the tar sand oil, taken from Seely et al. (1, 2).*
[2] *One of the general Lloydminster group of heavy oil pools near the boundary of Alberta and Saskatchewan obtained by pumping.*
[3] *Geological age: L.C.–Lower Cretaceous; U.C.–Upper Cretaceous; D–Devonian.*
[4] *Wt. %.*
[5] *Well-head prices obtained from Dept. of Mines and Minerals, Edmonton.*

Aerial view of pilot plant where Imperial, Cities Service, Richfield and Royalite have combined to determine commercial feasibility of extracting hydrocarbons from the Athabasca oil sands. The oil sand escarpment is shown in background. (Photo courtesy Cities Service Athabasca, Inc.)

vonian age (*3*). It is overlain by marine shales called the Clearwater formation. No clear evidence that the McMurray formation is marine has been found and it is generally assumed to be of fresh-water or brackish-water origin.

The sand, silt, and clay of the McMurray formation are considered to have originated from the Precambrian Shield to the east, and is regarded as a deltaic and shoreline deposit on the edge of this Shield.

The origin of the oil in the Alberta tar sand deposit is still a matter of discussion. One school of thought (*4, 5, 10*) considers that the oil had a Lower Cretaceous origin while another group (*6, 7*) favors a Devonian origin for the oil.

Recent chemical studies (*8, 9, 11, 12*) on trace components of the Alberta tar sand oil and the more conventional oils of Western Canada have shown considerable support for the Lower Cretaceous origin theory. However, regardless of its origin, the tar sand oil gives products on refining very similar to those obtained by refining normal crude oils (*13*).

The oil is found impregnating the beds of sediments in accordance with their porosities and permeabilities. The beds which consist of comparatively clean sand are well filled with oil and constitute the good-grade tar sand. In the case of the interbedded variety of tar sand and shale, only the sandy portions of the sediments are well filled with oil. The shale beds contain oil to a small degree, or not at all, depending on their varying nature.

In freshly-mined good-grade tar sand, a portion of the water appears to be present as a film around the mineral particles. This prevents the oil from having direct contact with most of the mineral surfaces, thus facilitating the removal of the oil from the tar sand in the hot-water washing process. The balance of the water is probably present as a disperse phase in the oil and as free water.

Typical core analyses of the Alberta tar sand deposit are presented in Table 2.

Oil recovery methods

The oil in tar sands cannot be recovered by conventional crude oil production methods due to the high viscosity of the oil in the formation and the lack of a normal reservoir drive. Two alternatives are available: 1. *in situ* development, which requires production of a satisfactory subsurface drive mechanism to move the oil to production holes and 2. surface treatment, in which tar sand is mined either by open-pit mining or block caving, and the oil is recovered in a surface plant.

To enable the tar sand oil to flow to production holes, the viscosity must be decreased considerably and a suitable drive mechanism provided. The most obvious way to reduce the viscosity of the oil is to heat it; the next most obvious way is to dilute the oil with a suitable solvent.

The suggestion has been made that some method of heating the oil *in situ* be employed, followed by water flooding. Electrovolatilization has also been proposed (*14*). Very recently, the use of nuclear energy, for heating the deposit has been suggested (*19*).

Currently a subsurface combustion method appears to hold the most promise for *in situ* development of the tar sands.

Since tar sand outcroppings in Alberta occur over such a large area, it was only natural that initial investigations into recovery of the oil should have stressed open-pit mining of the tar sand and surface methods for treating the material. Hence, much of the work on the Alberta tar sands has been directed towards locating sections which showed a sufficient volume of good-grade tar sand under reasonable overburden to warrant exploitation by open-pit mining and to the study of surface methods for oil recovery.

Four surface methods for oil recovery have been proposed, namely, solvent extraction, hot-water washing, cold-water washing, and fluidized retorting.

Solvent extraction. Although solvent

Table 2. Core analyses of Alberta tar sand deposit (18).

	Oil content wt. %		Water content wt. %	Mineral aggregate		
	Range	Avg.		−200 mesh % Range	Avg.	Avg. clay content of −200 mesh, %
Good-grade tar sand*	10-17	13-14	2-5	4-20	10	< 10**
Interbedded tar sand and shale	4-10	6-7	9			
Shale	0-4	1-2	10-15			20

* *The porosity of good-grade tar sand varies between 35 to 45%; total liquid saturation (oil plus water) varies between 65 to 100%; the permeability of the mineral aggregate is around 1 to 10 darcys. Tar sand weighs approximately 125 lb./cu. ft.*

** *Represents about 1% of total mineral aggregate.*

extraction would be effective, there is grave doubt that solvent losses could be held to a satisfactory minimum when handling high quantities of solids.

Hot water washing. The Research Council of Alberta concentrated on the hot-water washing method because it seemed to offer the most promise (*15, 20, 21*). As developed by the Research Council, the process operates at around 175°F and permits considerable variation in operating conditions. The process was satisfactorily demonstrated in the summer of 1949 during the operation of a pilot plant at Bitumount. At times, the throughput exceeded 500 tons of tar sand per day. The oil was recovered as a froth which contained around 30% water and about 5% mineral matter. The primary yield was augmented by passing the underflow from the water settler through a conventional flotation cell, thus allowing a recovery of at least 95% of the oil. A very important feature of the process, as applied to freshly-mined Alberta tar sand, is that no reagents are required, that is, no diluent, alkali, or wetting agent. Heat is conserved by recirculating the hot water.

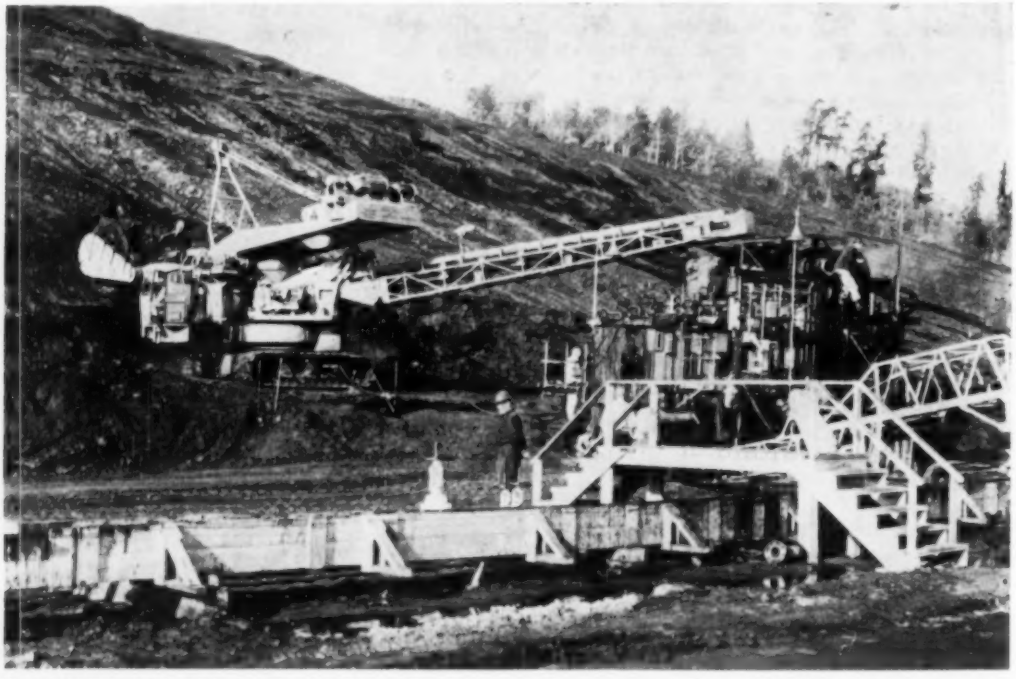
Although the pH of the plant water is of minor importance in the hot-water washing process, the pH of the tar-sand pulp immediately prior to separation should be around 7 for best separation results (*20*). A pulp that is neutral or slightly alkaline is preferred. Fortunately, freshly-mined Alberta tar sand has a pH of about 7.

Cold-water washing. The cold-water washing method, as developed by the Canada Mines Branch, Ottawa, operates at around 77°F (*22*). It requires that the oil in the tar sand be made considerably less viscous by adding an amount of diluent equal in weight to the oil in the tar sand. The diluent has the approximate volatility of kerosene. Also, it is necessary to add a monovalent alkali such as soda ash, and a wetting agent. The diluted oil product, before settling, contains about 25% water and 2.5% mineral matter. The process was operated on a small pilot-plant scale, the maximum throughput of tar sand being about 300 lb./hr., or 3.5 tons/day. The oil recovery by this process was also around 95%.

The Blair report (*23*) considered the hot-water washing method to be the more economical since no reagents are required and there are no diluent losses. Consequently, the Blair report included the hot-water washing method in its sequence of operations for tar sand development by surface treatment.

Fluidized retorting. The development of the fluidized solids technique for catalytic cracking led to its application by the National Research Council, Ottawa, in the retorting of tar sand (*16*). This coking operation, at a temperature of about 960°F, produces a dry fluid distillate having a gravity of 16° A.P.I. and a sulfur content of 4%, the yield of distillate amounting to about 85% by volume. However, during the compilation of the Blair report it appeared that the capital cost of equipment to retort huge volumes of tar sand in a fluidized bed would be too great, and this would be reflected in a higher cost per barrel for the product. In addition, the disposal of enormous volumes of hot sand tailings would be a problem. A more feasible arrangement for the fluidized solids technique seemed to be the "dehydration-coking" in one operation of the wet crude oil obtained as an oil froth in the hot-water washing process. When this was tried (*23*) it was found that the yield of product, gravity, and sulfur content appeared similar to what was obtained when the tar sand itself was retorted.

Furthermore, the Blair report stated that the sulfur content of the coker distillate produced by fluidized retorting would have to be reduced considerably before the distillate would be of acceptable quality for subsequent refining and marketing. Mild hydrogenation was considered to



View of pilot plant mining and extraction units at base of oil escarpment. The mining equipment removes the tar sands and conveys it to the extraction unit where liquid hydrocarbons are removed and forwarded to the refinery. (Photo courtesy Cities Service Athabasca, Inc.)

Table 3. Estimated production costs of Alberta tar sand oil.

Production item		Cost per barrel
Open-pit mining, including overburden removal		$0.55
Hot-water separation of the oil from the tar sand plus fluidized coking of the wet crude oil		0.72
Desulfurization of the fluidized coker distillate by mild hydrogenation		0.81
Pipeline transportation charges:		
(a) From tar sand area to Edmonton	$0.28	
(b) From Edmonton to Superior, Wis.	0.55	
(c) Storage and all other transportation expenses additional to the direct line costs	0.19	
	$1.02	$1.02
Total production cost at Superior		$3.10*

** The pipeline transportation charges of $1.02 are on a basis that provides a satisfactory profit directly on the capital involved. However, no specific allowance was included in the mining and processing costs totalling $2.08 for interest or profit on the capital.*

represent the most effective way of accomplishing this reduction. A temperature of about 800°F. and a pressure of 1000 lb./sq. in. gauge proved adequate (*17*).

Economic aspects

The Blair report (*23*) on the Alberta tar sands outlined a sequence of operations for possible commercial development of the portion of the tar sand deposit readily available by open-pit mining. The sequence involved removal of the overburden, open-pit mining of the tar sand, hot-water separation of the oil from the sand, fluidized coking of the wet crude oil, desulfurization of the distillate produced by the coking, and pipeline transportation of the product from the tar sand area to the Great Lakes market. Table 3 shows the breakdown of costs provided by the Blair report, as of 1950, for this sequence of operations.

The desulfurized oil product has a gravity of 26° A.P.I., contains 0.26% sulfur, shows a Conradson carbon residue of 1.22%, and consists of about 88% gas oil and 12% gasoline. The gas oil has characteristics very similar to those of No. 2 furnace oil. Based on a value of $3.00/bbl. at Superior, Wisconsin, for Redwater crude oil of 30° A.P.I., it was assumed in the Blair report that the desulfurized oil product from the tar sand would have a value at Superior of at least $3.50/bbl. In arriving at this estimate, allowance was made for expenses that would be incurred in adjusting the quality of Redwater crude oil to a comparable basis.

The net result of the above estimates—$3.10/bbl. for total production cost and $3.50/bbl. as the value of the product—is to show a possible realization of $0.40/bbl. Based on a total capital expenditure for mining and processing of $43,600,000 on which interest and profit are required, and with an annual production of six million barrels (20,000 bbl./day for 300 days), the profit of $0.40/bbl. would yield 5.5% on the investment.

As a sequel to the Blair report, a tar sands conference was sponsored by the Government of Alberta and held at Edmonton in September, 1951. About 125 technical personnel from oil companies and research organizations attended. The conference lasted 3½ days and dealt with all phases of the tar sands, namely, geology, mining, oil recovery, oil refining, and pipeline transportation. The conference focussed the attention of the major oil companies on the Alberta tar sand deposit and resulted in a considerable amount of exploratory core drilling, core analyses, and investigational work on the oil. Leases have been taken out at a number of locations.

David S. Pasternack is associate research officer in the Research Council of Alberta, in Canada. He has spent a total of seventeen years on the study of Alberta tar sands and tar-sand oil. This work has included production methods and assistance in operating the two government of Alberta pilot plants in the tar-sand area, one on the Clearwater River and the other at Bitumount. A graduate of Queen's University with a B.Sc. in chemistry, Pasternack took his PhD. at McGill.

In bringing the conclusions of the Blair report up-to-date, as of 1958, it is necessary to consider the changes that have taken place during the past eight years. A recent communication from Blair (*24*) states that, in general, operating costs and the value of the oil products appear to show similar percentage increases. On this basis alone, the profit per barrel would still be quite similar to the $0.40/bbl. shown in the Blair report.

Of course capital costs have increased during the period by about one-third, but on the other hand, marked technological advances have taken place, as in the case of hydrogenation. For example, the Blair report considered that the hydrogen requirements in the hydrogenation of the coker distillate would be 1000 cu. ft./bbl. at a cost of $0.25/1000 cu. ft., whereas Warren *et al.* (*17*) later found that 600 cu. ft./bbl. would be sufficient. The net result is, probably, that the estimate of a 5.5% return on the investment as given in the Blair report would not be substantially changed.

One other point should be mentioned in this connection. The Blair report was based on a production of 20,000 bbl./day. Although that represents a plant of substantial proportions, it is not necessarily the optimum size for efficiency and for obtaining the lowest over-all costs per barrel either in operating costs or in capital expenditure. A plant of 50,000 or 100,000 bbl./day would reduce pipeline costs to Edmonton and should improve the economic features of tar sand development.

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What's in Vol. 55, 1959 Number 25

Reaction Kinetics and Unit Operations

Reaction rates in chemical engineering science, Hugh M. Hulburt

Chemical reactions consist in the redistribution of electrons between nuclei. The laws which govern their interactions must be our most fundamental concern. These are concisely summarized in the Schrodinger equation and the postulate of Coulomb's law for the force between charged particles.

Transport processes with chemical reactions, Stephen Prager

The general transport equations are briefly developed and their simplification is discussed. They are then applied to (1) reactions with bulk flow only, (2) reactions accompanied by diffusion and heat conduction, both with and without the assumption of local chemical equilibrium, (3) diffusion controlled surface reactions, (4) systems in which reactions give rise to volume changes, and (5) the steady state. For systems with nonlinear kinetics the method of moments is shown to give good results with a relatively small amount of effort.

Turbulent transport in chemical reactors, John Beek, Jr., and R. S. Miller

To predict the behavior of a reactor under specified conditions, one must be able to calculate not only the rates of whatever chemical reactions are going on but also the rates of whatever transport processes are involved. This paper lists the transport processes and discusses them.

Intraparticle diffusion in catalytic systems, Paul B. Weisz

Diffusion transport may have various effects on the measured rate of conversion. The state of application of diffusion equations to chemical rate processes is discussed. Examples of various cases of intraparticle chemical conversion and generally useful methods of evaluating diffusion effects are given. Diffusion-transport criteria can often be used to investigate reaction kinetics involving intermediate species.

Stability of chemical reactors, C. H. Barkelew

It has been common practice to base the stability aspects of reactor design primarily on pilot plant or laboratory experience. Recently, however, several publications have appeared describing analyses of the thermal behavior of reactors, made in the hope that a suitable theoretical treatment could save expensive pilot-plant experimentation. This paper describes these efforts and presents a new, hitherto unpublished method for designing stable tubular reactors.

Chemical reaction-system dynamics, Alan S. Foss

Recent developments in the dynamics of chemical-reaction systems are contributing toward improved control of today's rapid chemical processes. This paper reviews these developments in some detail, placing emphasis on the methods and techniques of analysis. Also, the gaps in our present knowledge are pointed out, and some lines of attack to fill them are suggested.

Progress in the fundamentals of heat transfer, M. T. Cichelli

Progress in heat transfer science during the past fifty years is briefly reviewed, with emphasis on those developments which have had the greatest impact on chemical engineering practice in this country.

Future trends in heat transfer technology, Donald Q. Kern

Future developments in thermal process technology will be derived from the design practices employed in nuclear reaction, cryogenics, rocketry, missile technology; from extensions of current chemical engineering techniques; and from the adaptation of advanced mathematical tools to computer solutions. Rockets and their related problems are the dominant influence in outmoding current thermal-processing concepts.

Mass, heat, and momentum transfer between phases, T. K. Sherwood

Mass may be transferred, as by evaporation of a liquid into a gas in a wetted-wall tower; heat is transferred if tube and fluid are not at the same temperature; and momentum transfer from the fluid results in a shear stress at the tube wall, causing a decrease in fluid pressure along the tube length. The subject of the present paper is the interrelationships of these three transfer processes.

Progress in fractional distillation, R. L. Geddes

A brief outline of important developments that contribute to present knowledge of design of fractionators is given in historical sequence. Some comments on the present status and future problems from a chemical engineer's viewpoint are offered.

Liquid-liquid extraction theory and practice, Robert B. Beckmann

The objectives of this paper have been set forth as the presentation of

the theory and practice of solvent extraction—its history (in regard to significant developments), current practice, and a few prognostications for the future. Because of the enormity of the general field of solvent extraction the author decided to limit his discussion to the fundamentals of mechanism and theory as they pertain to liquid-liquid extraction in general and specifically to presently popular commercial extraction equipment.

Progress in separation by sorption operations—adsorption, dialysis, and ion exchange, G. P. Monet and Theodore Vermeulen

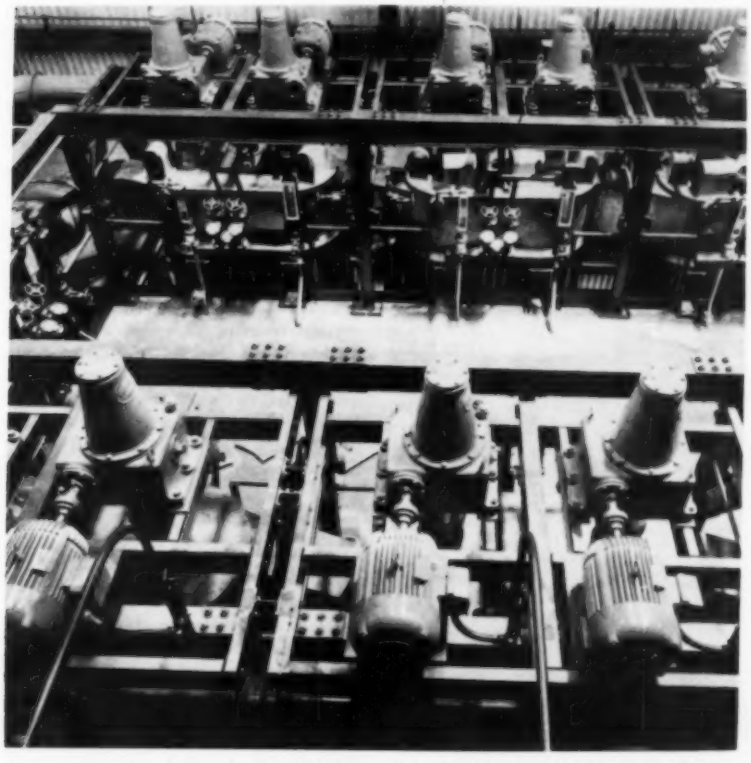
The object of this paper is to outline briefly the present status of quantitative knowledge about adsorption, dialysis, and ion exchange. First general effects which are believed to apply to all three fields are discussed, and then are considered specific effects which are caused by the sorbent materials used.

Principles of gas-solids separations in dry systems, S. K. Friedlander

In the discussion that follows, the mechanics of fluid-particle systems will be used to explain the functioning of each class of device developed to handle the wide range of problems encompassed within suspension concentrations and particle-size limits. The emphasis is on recent advances in the field and on areas which may prove fruitful for further research.

The art and science of liquid filtration, H. P. Grace

The purpose of this paper is to describe in a general way the present state of theoretical knowledge as applied to solution clarifications and to cake filtration and its limitations; to consider the major problems in measurement techniques and their potential solutions; and to point out the potential areas of development that are most likely to yield significant improvements in filtration performance.



An application of the fundamentals in this Symposium Series area. Portion of reactor floor where plant foods are chemically reacted. Photo by CalSpray Chemical Corp.

Separation by crystallization, Robert A. Findlay and Dwight L. McKay

Crystallization could be the basis of a separation method of wide usefulness, particularly in the field of organic chemicals. Advantages which are especially applicable in this field are minimizing the decomposition of heat-sensitive substances and separation of organic isomers which can be separated practically in no other way. Application has been hindered by lack of chemical engineering development.

Mixing of liquids, J. H. Rushton and J. Y. Oldshue

Mixing of fluids in chemical processing usually involves an intimate and homogeneous distribution of all liquid components, gases, and particulate solids which may be involved. The most common device to bring about mixing is some form of rotating impeller, driven by a shaft attached to a power-transmission device connected to an electric or other motor.

Mixing of solids, Sherman S. Weidenbaum

Highlights of solids-mixing studies are given, based on a critical and interpretive review of American and foreign literature and other pertinent material. Degree of mixing, theoretical frequency distributions, rate studies, and equipment are discussed. Areas for future investigation are suggested.

Size reduction, Lincoln T. Work

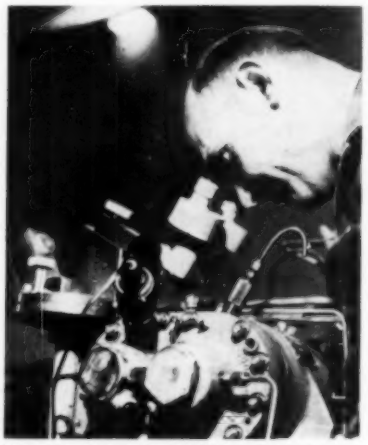
The creation and control of particle size goes under many names, some pointing to the production of particles in a desired range of sizes. This paper will discuss the aspects of solids only, with particular reference to size reduction and some reference to size enlargement.

Drying—its status in chemical engineering in 1958, W. R. Marshall, Jr.

Historically, drying is one of the oldest operations in chemical engineering, and yet at this date its theoretical development has not progressed as far as many other chemical engineering operations. The objectives of a drying operation can be manifold, and it is difficult to name a common objective, other than moisture removal. Consequently, drying problems generally involve a variety of secondary objectives.

New synthetic jet plane oil

Petroleum-based jet lubricant has long storage life, superior performance characteristics under extreme temperature conditions.



Special microscope fitted to test machine at Esso Research Center, Linden, N. J., for investigating performance of jet plane lubricants.

STARTING UP A JET PLANE'S engine in the Arctic at 65 degrees below zero should be a trouble-free operation from now on, with development of new petroleum-based synthetic lubricants. Pioneer in this field has been Esso Research and Engineering, which has just come up with a jet plane oil which can be stored even in tropical areas for five years or longer without deterioration.

Composition of the new lube oil, WS-4040, is being closely guarded, but details of qualification tests made at Phoenix Chemical Laboratory have been released (see accompanying table).

Key property is the change in kinematic viscosity after standing at extremely low temperatures, such as are encountered in Arctic operations. The new oil, according to Esso scientists, shows little or no change in viscosity after standing for up to 72 hours at minus 65°F, and its viscosity after this period of time, 11,418 centistokes, is well below the military standard of 17,000 maximum.

Flash and pour points are more than satisfactory, as are corrosion rates at high operating temperatures in contact with the various metals generally used in jet engine construction.

"H" rubber swell (see table) is a measure of the swelling induced by the lube oil in a typical type of rubber used in seals for military jet engines.

Esso emphasizes the excellent foaming characteristics of the new lube oil. The figures in the table, such as 100/0, signify that from a given quantity of oil at a given temperature, a certain number of cubic centimeters of foam are formed instantaneously and disappear completely in a definite period of time (usually 5 minutes). It will be seen that the new Esso lube shows up extremely well under the test conditions.

Performance of new lube oil, WS-4040 in Mil-L-7808 Qualification tests.

(Qualification Tests at Phoenix Chemical Laboratory)

Test	Mil-L-7808D Specifications	WS-4040
KV/210°F., cs.	3.0 Min.	3.14
100°F., cs.	11.0 Min.	12.05
−65°F., cs.	13,000 Max.	11,400
−65°F., cs., after 3 hrs. at −65°F.	13,000 Max.	11,418
Vis. Stability after 3 hrs. at −65°F.	6.0 Max.	0.0
−65°F., cs., after 72 hrs. at −65°F.	17,000 Max.	11,488
Flash Pt., °F.	400 Min.	425
Pour Pt., °F.	−75 Max.	<−85
TAN (Total acid number)	..	0.07
One Hr. SOD Pb Corr., Mgs./Sq. In.	6.0 Max.	0.00
347°F. Corr. and Ox. Stabil., Mgs./Sq. Cm.		
Cu	±0.4	+ 0.023
Mg	±0.2	0.000
Fe	±0.2	+ 0.031
Al	±0.2	0.000
Ag	±0.2	+ 0.015
Change in Vis./100°F., %	−5 to +15	+ 1.8
Change in TAN	2.0 Max.	0.52
Static Corrosion at 450°F., Mg./Sq. In.		
Cu	3.0 Max.	− 0.02
Ag	3.0 Max.	− 0.18
Compatibility	Pass	Pass
"H" Rubber Swell, %	12—35	30.9
Foam: Seq. 1, 75°F.	100/0	20/0
Seq. 2, 200°F.	25/0	10/0
Seq. 3, 75°F.	100/0	5/0
Panel Coke, 600°F., Mgs.	80 Max.	31.6
Evap. Loss, %	35 Max.	16.06
Deposition rig demerit rating, average of two runs	5.5 Max.	2.0

Economics

Superior oils based on petroleum raw materials, points out Esso, have basic advantages of lower price and wide availability over those based on chemicals of vegetable origin. This could be of major importance in an all-out emergency requiring large volumes of "synthetic" lubricants. Annual military demand for jet engines is estimated at about 1,500,000 gallons, use in civilian jet planes may swell the market for the new oil.

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CEP

COMPUTER PROGRAM abstracts

The Machine Computation Committee of the A.I.Ch.E. is interested in receiving program abstracts. Once again the Committee wishes to emphasize the three rules for participation in the interchange program:

1) Abstracts submitted for publication must follow the form published in *CEP* (January, 1959) and in the *Guide*.

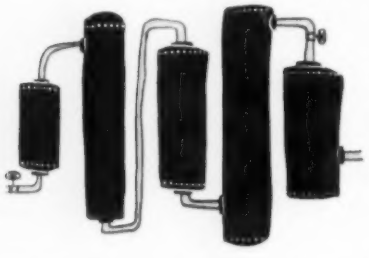
2) Abstracts must be sent to the Machine Computation Committee c/o A.I.Ch.E.

3) All questions relating to published abstracts must be sent to the Committee c/o A.I.Ch.E. in New York.

Multicomponent extraction of heavy metal nitrates with tributyl phosphate solvents (045)

Donald R. Olander
Department of Chemical Engineering, University of California

Description: The program calculates the number of theoretical extracting and scrubbing stages required for the separation of heavy metal nitrates [e.g. $UO_2(NO_3)_2$, $Zr(NO_3)_4$, $La(NO_3)_3$] from an aqueous feed into a tributyl phosphate-inert diluent solvent. Separation requirements are specified by a decontamination factor and a product recovery. A maximum of five



macro components and 15 trace constituents can be accommodated.*

The minimum flow ratios for the separation are calculated first, assuming that the pinch points for each section occur at the feed stage. Due to the highly nonlinear nature of the distribution coefficients, this assumption is not always valid; in many cases, the required number of stages is abnormally large even though the flows are well above the calculated minima. This indicates the approach to a different type of equilibrium restriction in the column.

The stepwise calculations are based upon the method outlined by M. Benedict and T. H. Pigford, *Nuclear Chemical Engineering*, McGraw-Hill, New York (1957).

Recovery and decontamination specifications fix the distribution of two components between the extract and the raffinate. The split of the remaining unspecified macro components cannot be fixed in advance, and must be assumed before the stage-by-stage calculations are begun. The validity of the assumed raffinate concentration is checked by feed-point matching at the end of the column calculation.

If the feed-point match of each unspecified component is better than 1%, the calculations are completed; if not, new raffinate concentrations are chosen by a modification of Newton's rule for determining the roots of a polynomial. If the assumptions are so much in error that the calculations diverge and no feed-point match is obtainable, new assumptions are read into the calculation.

After the behavior of the macro components has been computed, the distribution of the trace components is determined.

Computer: IBM 704, 32K Core, 1 tape, input on cards.
Program language: Fortran I.
Running time:

No unspecified components	1 minute
One unspecified component	5 minutes
Two unspecified components	15 minutes
Three unspecified components	30 minutes

Comments: The program can handle aqueous feeds consisting of any of the heavy metal nitrates known to react with tributyl phosphate to give complexes of the form $M(NO_3)_x \cdot y$ TBP, where

$1 \leq x \leq 4$ and $1 \leq y \leq 3$.

Although the computational method is not directly applicable to two-section columns with an organic feed or one section, top or bottom fed units, the present program need only be slightly altered to accommodate these variants.

The accuracy of the feed-point matching is limited by the use of a linear interpolation technique, which could introduce appreciable error if the organic phase composition were changing rapidly near the feed point.

The entire computation rests upon the validity of the assumption that activities can be replaced by concentrations in the complexing equilibrium expression. Furthermore, mass action constants for the relevant complexing equilibria are required as input data.
Availability: A program manual will be written if sufficient interest develops.

General analysis of variance (047)

Allan W. Dickinson
Monsanto Chemical Company
Applied Mathematics Section
800 N. Lindbergh Blvd.,
St. Louis, Mo.

Description: The program performs analysis of variance computations for up to twelve factors at any number of levels. Sums of squares, degrees of freedom, and mean squares are computed for all main effects, first and second order interactions and the residual. Components of variance for all main effects or for selected main effects are available on an optional basis. Also printed are tables of means for main effects, first and second order interactions. Any degree of multiple or fractional replication can be handled. Standard transformations on the input data (log, square root, etc.) are available.

continued on page 82

**Trace constituents are those whose concentrations are sufficiently low such that they need not be included in the TBP and aqueous nitrate material balances. Therefore, their behavior in the column can be computed after the main calculations have been performed on the macro components.*

IBM 1620 *data processing system*

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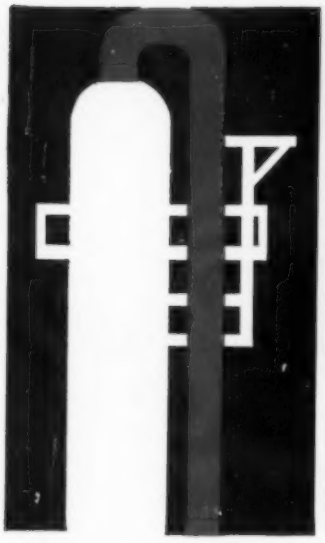

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Computer abstracts

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Computer: IBM 704, 8K core, 1 tape (optional).

Program language: Fortran II.

Comments: Sums of squares are computed in single precision floating point arithmetic. If greater accuracy is desired, the computer can be instructed to perform the analysis on deviations from means rather than from the raw data.

A choice between printer output and tape output is available through a sense switch control.

Availability: The manual on this program will be made available if there is sufficient interest.

Thermodynamic functions of diatomic gases (048)

J. Gordon and R. Robinson
Reaction Motors Division, Thiokol Chemical Corporation, Benville, New Jersey

Description: This program computes the free-energy function, mean specific heat, entropy, heat capacity at constant pressure, and enthalpy for a pure ideal gas at 298.15 and 300 to 6000°K, including generalized correction terms for anharmonicity, vibration-rotation interaction and rotational stretching according to the method of Pennington and Kobe, *J. Chem. Phys.*, 22, 1442, (1954) and including the effect of up to three excited electronic states.

Method: Input data include all the standard molecular constants as given by Pennington and Kobe, *J. Chem. Phys.* 22, 1442 (1954). The electronic-state partition function is handled separately.

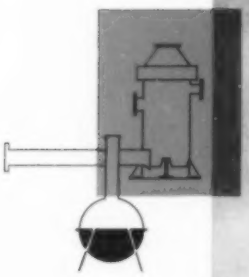
Computer: LGP-30 or standard IBM-650 (with 2000-word drum and 653 attachment).

Program language: Soap IIA (Symbolic Optimal Assembly Program).

Running time: Three seconds per temperature.

Comments: Over 120 diatomic gases have been treated using this program or variants.

Availability: A program manual can be made available for publication should sufficient interest develop. Published by Butterworths in Proceedings of the 1959 Fall Meeting, Western States Section, Combustion Institute. RMD Technical Report available on written request.



BOARDMAN

Left: Self-supporting stack of carbon and stainless steel for the Chemicals Plant Division of Blaw-Knox, used at an Atlantic Refining Company refinery. Below: 10′ OD x 50′ after cooler, composed of high tensile steel, for the Columbian Carbon Company.

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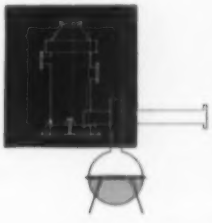

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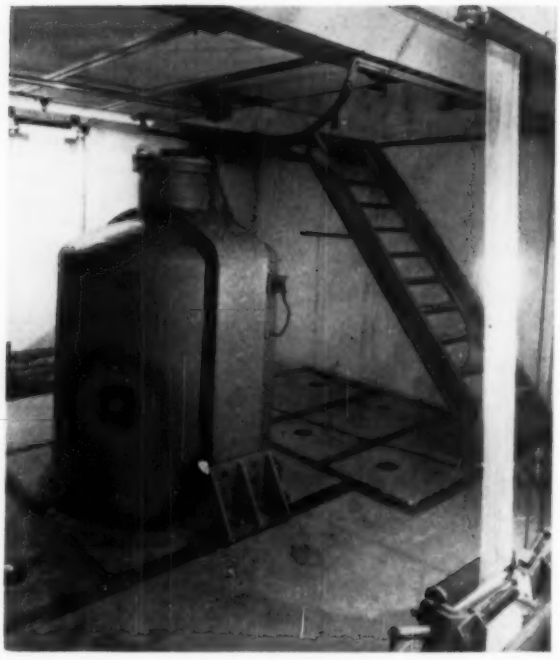
industrial news

Two-way stretch assures perfect packaging fit

Radiation-crosslinked polyethylene film uses "high-shrink" energy to produce clear skin-tight contour packages.



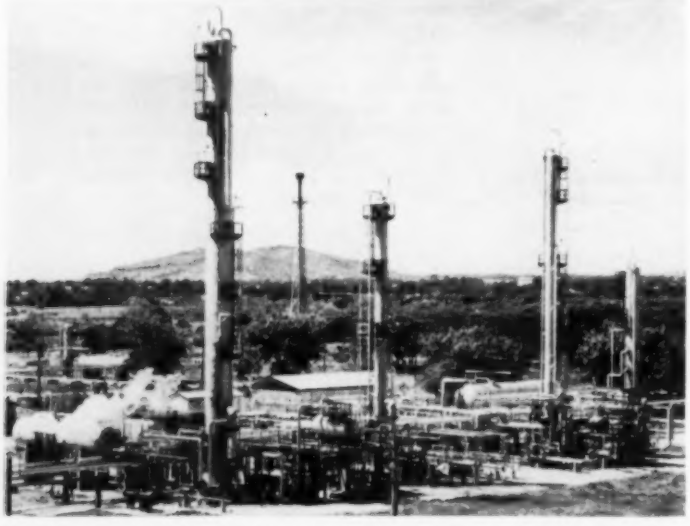
Electron beam "dome" room at W. R. Grace's Simpsonville, S. C., plant. The dome houses all electron components which are kept under pressure by an insulating gas.

Electron irradiation of polyethylene film with up to 2 million volts at W. R. Grace's Simpsonville, S.C., plant, increases its strength more than 500% and makes it possible to stretch it more than 200% in both directions. Exposed to hot air or water at 180°, the new film, called Cryovac L, immediately shrinks by 20%, and will continue to shrink equally in all directions as the temperature is increased until it returns to its original size. The stretching property, termed by Grace "biaxial orientation," is the direct result of crosslinking of the chains of the original linear polyethylene under electron bombardment.

The stretching characteristic of the film, says Grace, has made possible development of new packaging techniques that use the "shrink energy" of the film to do much of the wrapping and sealing of the package itself. The film can be made to shrink itself tightly around the tops of baking pans, produce trays, and even around stalks of celery.

Current price for the new film is 3¢ per 1,000 square inches, in a one mil thickness—comparable in cost to cellophane and conventional polyethylene, less than Saran. Present capacity at Simpsonville is "several million pounds per year," says Grace. Installation of more electron beam generators is in the works.

Patents issued are said to cover not only polyethylene, but all polyolefins, including polypropylene and various copolymers.



Plant and processing equipment at Chinese Petroleum's Kaohsiung Refinery were designed by Badger. Left, the deisobutanizer tower.

New alkylation plant in Formosa

900 bpsd aviation gasoline plant added to Chinese Petroleum refinery, uses H_2SO_4 Process for conversion.

A NEW AVIATION GASOLINE plant is the latest addition to the 35,000 barrel/a day petroleum refinery at Kaohsiung, Taiwan (Formosa). The Chinese Petroleum Corp. plant, with a design capacity of 900 bbl./stream day alkylate, uses the H_2SO_4 process for converting butylenes and propylenes, together with isobutane from the refining operation, into alkylates of high octane blending values. This process was developed primarily by Texaco Development Co.

Design consists of a sulfuric acid

continued on page 86

For more information, circle No. 92 ➤

built by Badger for

ATLANTIC

220 million lb/yr. wax plant of advanced design completed in 61 weeks

One of the largest, most flexible wax manufacturing plants ever constructed has recently been completed by Badger at the Atlantic Refining Company's Philadelphia refinery. The classic and widely used MEK solvent process* was the starting point for this ultra-modern plant. From there, Badger engineers created an unusually versatile design . . . a plant capable of processing eight different feedstocks through fourteen operations to produce corresponding grades of paraffin waxes (oil content 0.2%).

Plant capacity (265 tons/day) and the number and variety of processing steps made economical design a major engineering undertaking. Examples: the filter section includes fourteen 700 sq. ft. units of an improved design — the largest in the petroleum industry; the two compressors in the massive refrigeration section have a combined rating of 5,800 h.p. — equivalent to the capacity required to produce 4,200 pounds of ice per minute; the chiller-exchanger section consists of 33 units (sixteen scraped-pipe exchangers, seventeen scraped-pipe chillers) in a novel arrangement that simplifies maintenance and operation.

In spite of its size and the complexity of the engineering problems involved, Badger completed Atlantic's plant in less than fourteen months. This project is another example of how Badger engineering skill helps leading companies get more efficient, economical plants. Isn't this the type of service you deserve?

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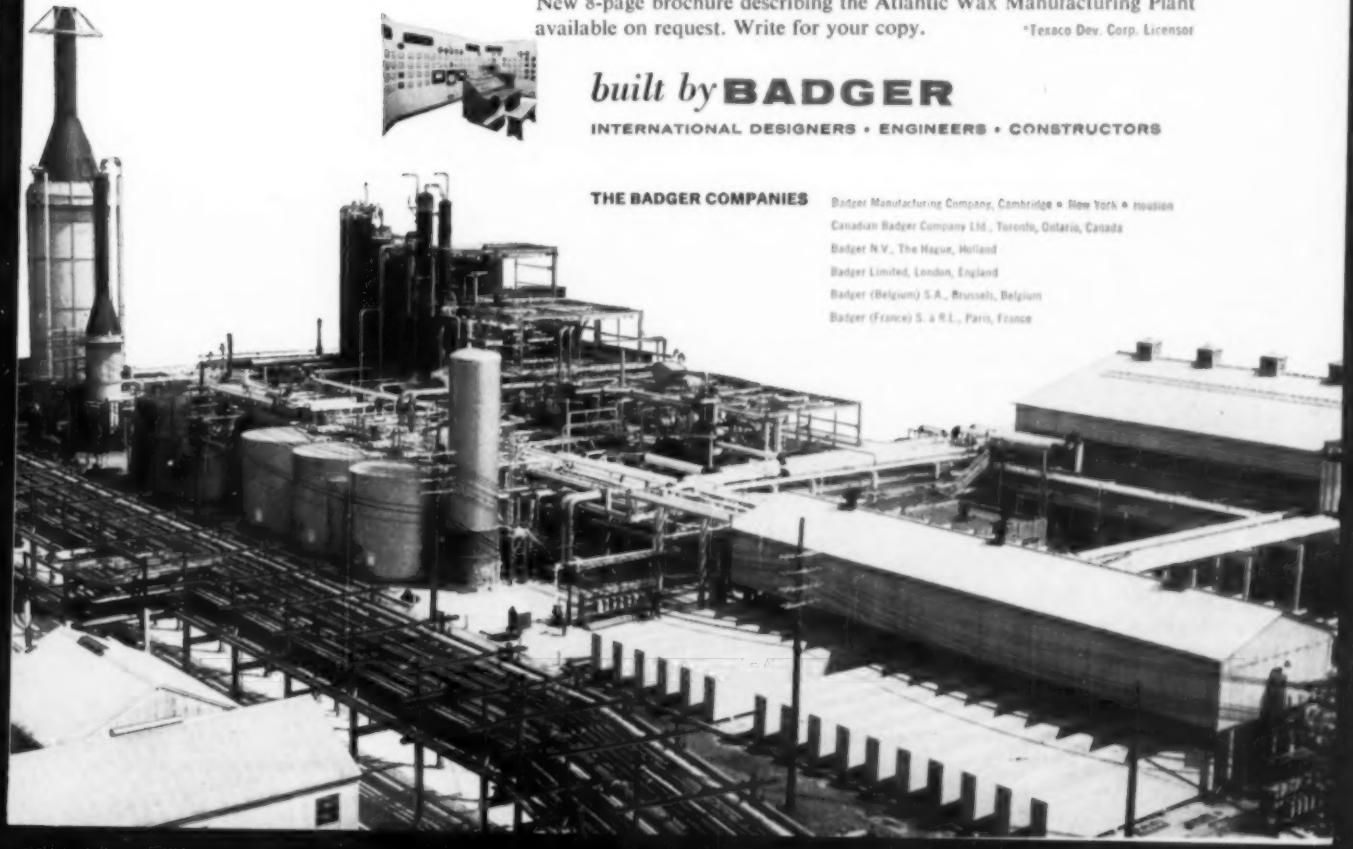

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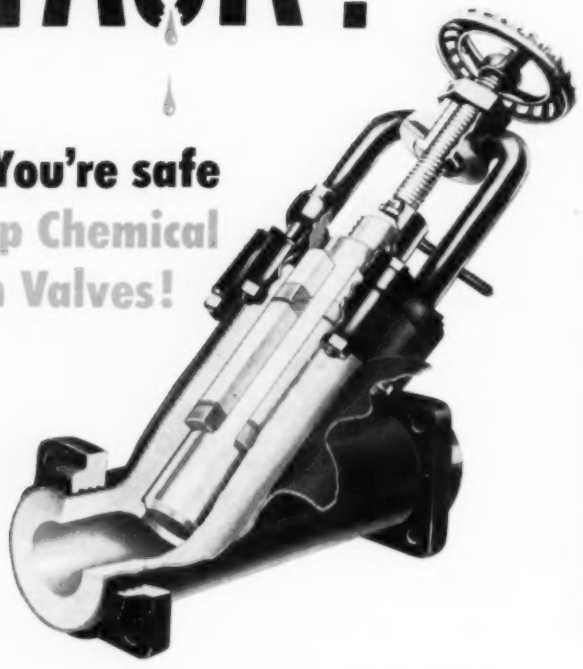

Now you can valve acids as easily as water! The solid porcelain of these Lapp valves is chemically inert, immune to corrosion from all acids (except hydrofluoric), and absolutely impervious. There's *extra* protection, too, in the TUFCLAD® armor that cushions the porcelain body against impact and insulates it against thermal shock.

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Alkylation plant

from page 84

alkylation processing unit, plus fractionating facilities for recycled fractions and high purity products. A Stratco contactor is used for the low temperature intimate mixing of sulfuric acid with the hydrocarbon feed stock.

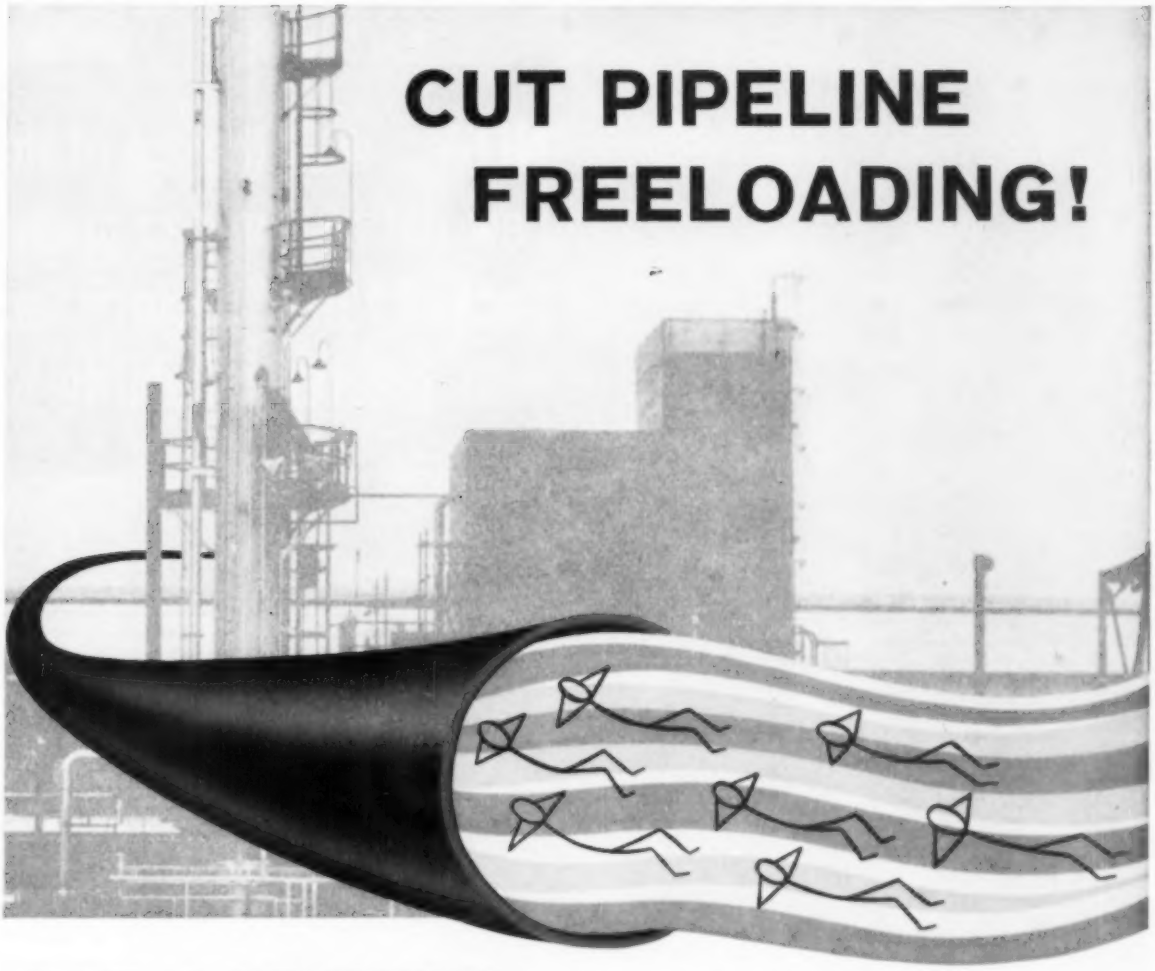
The plant was designed and engineered by Badger. While certain detailing and fabrication were done in Taiwan, most of the equipment came from the United States and Europe. Chinese Petroleum's own staff did the construction work.

Now in commercial production, the plant makes high octane blending value material exceeding the guarantees. A high percentage of the gasolines produced there are now being exported for use in other countries throughout the far east.

A proposal for a 50,000 electrical kilowatt boiling water reactor plant is under consideration by AEC. While this is designed to substantially increase in power per unit volume of fuel over present similar type reactors, it is hoped that further research can increase capacity of 75,000. Under the joint proposals from Consumers Power Company, Jackson, Michigan, and GE, San Jose, California, the two companies would handle the research and development angle under separate contract with the commission. AEC would support necessary research and development and waive fuel charges to an agreed amount. Proposed site is at Big Rock Point, Lake Michigan.

A small pressurized water reactor power plant now under consideration by AEC would use a reactor with a fossil fueled superheater, generating about 60,000 kilowatts of electric power. The Commission plans to construct it within the next year, in line with attempts to develop a reactor that would give economical electric power in a small plant. Bids for the operation of the plant are in from the City of Miamisburg, Ohio; Detroit, Michigan; Fort Pierce, Florida; Jamestown, New York; and the Dairyland Power Cooperative, La Crosse, Wisconsin.

A $9 million Air Force contract for production of pentaborane, awarded to Callery Chemical, will put present plant facilities at Muskogee, Oklahoma, to work within the next few months.



AIR LIQUIDE eliminates "dead head" gas by low-temperature separation

Here's the way to rid pipelines of unwanted nitrogen, upgrade natural gas and make profits on superfluous yet valuable gases. *Install an American Air Liquide low-temperature gas separation plant,* economical to operate and requiring minimum of attention.

Many natural gas pipelines are carrying "dead head" nitrogen that builds up compression, increases transmission costs and reduces pipeline payload. This nitrogen is removed — at pipeline pressure — by the American Air Liquide process.

At the same time that your natural gas is upgraded, unwanted gases are removed — yielding further profit instead of going to waste as inerts, flue gases or engine exhausts along with a loss of valuable heat. To quote only one example, the extraction of helium offers considerable direct profit from this efficient, economical process.

For further information on our complete low-temperature service — from process engineering of complete plants and custom-designed equipment to technical consultation and plant erection — write or call us: Chrysler Building, 405 Lexington Ave., New York 17, N.Y.

PROFITABLE ADVANTAGES OF NITROGEN REMOVAL

1. Raises calorific value — more BTU's per pipeline.
2. Simultaneously removes heavier hydrocarbons for separate sale.
3. Enables compressors and pipelines to handle capacity payloads.
4. Improves flow characteristics: reduces density and viscosity; reduces pressure drops.
5. Cuts compressor fuel costs.
6. Produces helium simultaneously from helium-bearing gases.

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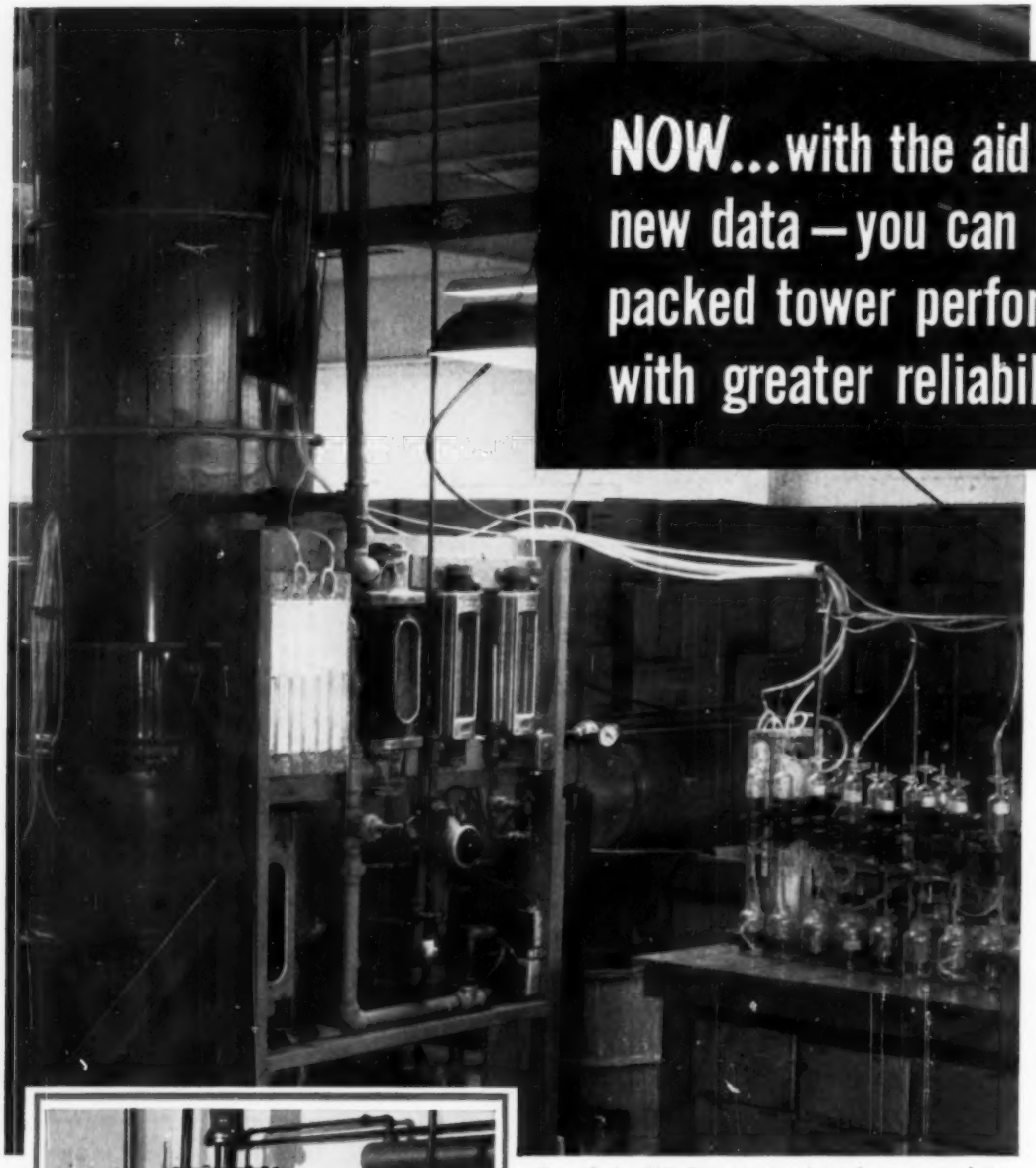
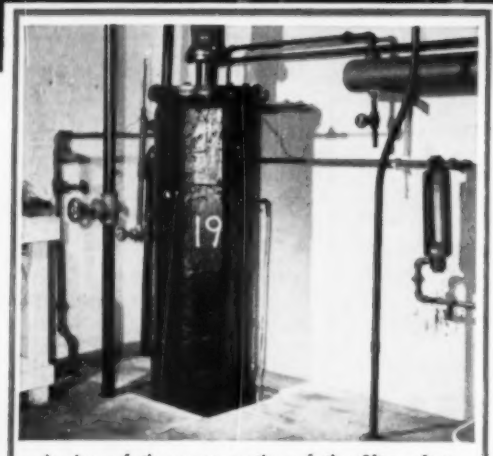
ENGINEERING & CONSTRUCTION DIVISION
OLDEST IN EXPERIENCE NEWEST IN DESIGN
405 LEXINGTON AVE., NEW YORK 17, N.Y

For more information, turn to Data Service card, circle No. 65

NOW...with the aid of this new data—you can predict packed tower performance with greater reliability



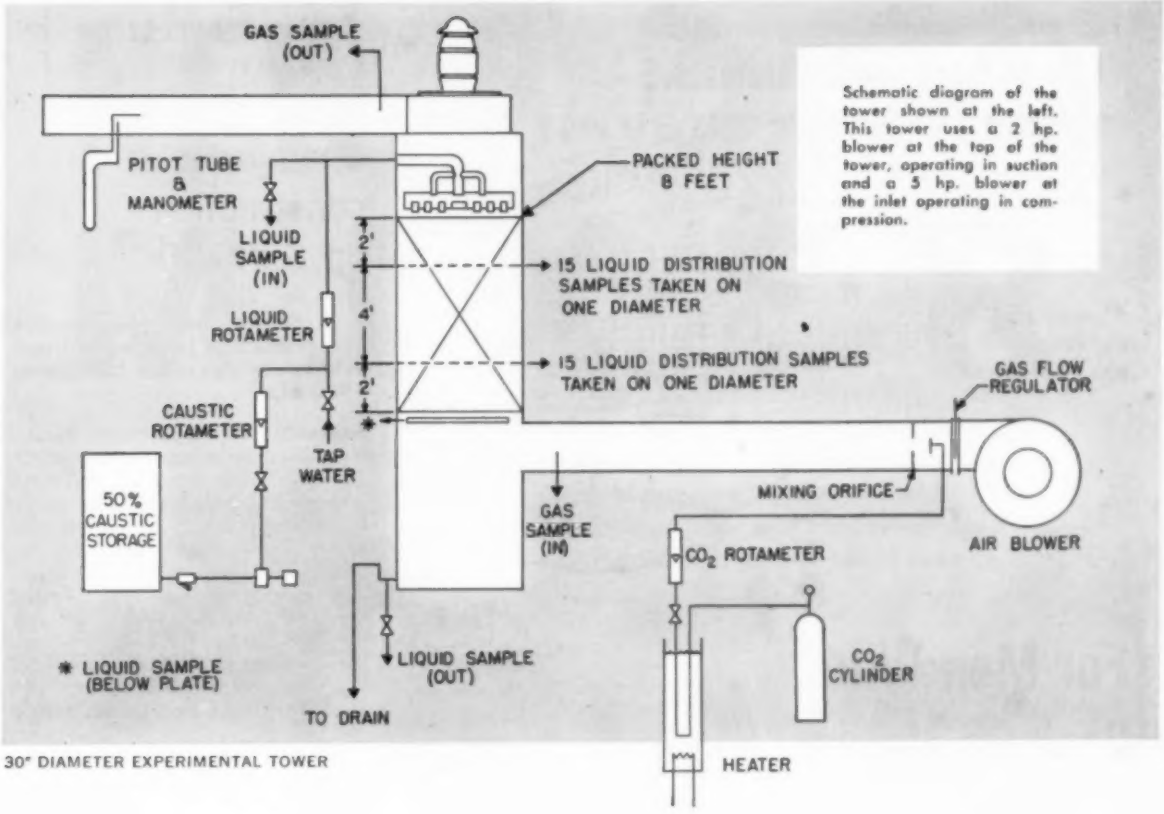
One of the 30" diameter experimental towers used to accumulate gas mass transfer coefficients and pressure drop data on tower packings of various types and sizes.



A view of the upper section of the fifteen foot high, 24" diameter distillation tower in U. S. Stoneware's Engineering Laboratories.

139-G

Up to a few years ago, data on packed columns sufficiently reliable to enable design engineers to predict performance in specific applications was virtually non-existent. Each new packed column installation had to be designed afresh, and was usually over designed to provide an adequate margin of safety. Data reflecting the experiences of plants operating towers of industrial size was generally not available; published data reflecting the work of universities conducted in small experimental towers, (because of limited availability of funds) while helpful, left much to be desired when used for scale-up.



Schematic diagram of the tower shown at the left. This tower uses a 2 hp. blower at the top of the tower, operating in suction and a 5 hp. blower at the inlet operating in compression.

30" DIAMETER EXPERIMENTAL TOWER

The development of high capacity tower packings such as the Intalox Saddle® and the Pall Ring brought with it the need for data that could be used to predict with reasonable accuracy the performance of large size towers.

Accordingly, The U. S. Stoneware Co., began building some four years ago a series of experimental towers of such size that data obtained from their use could be accurately translated in specific terms and could be used to predict the performance of large towers with reasonable accuracy.

In these past four years we have conducted hundreds of tests involving various types of tower packings, distributors, packing support methods, in absorption, fractionation, stripping and distillation. Test runs have been repeated over and over again to be sure that the data obtained would reliably indicate what could be reasonably expected.

Data obtained from these tests have been used by our engineers in designing towers up to many feet in diameter and performance of the completed tower has almost invariably equalled or exceeded anticipated performance.

This data is now being released for general distribution to chemical engineers everywhere without cost or obligation. The first release covers more than fifty graphs showing performance of various packings with data reflecting capacity and efficiency, etc. If you would like to receive a set and be placed on our mailing list for future releases as they occur please write us on your company letterhead. They will be sent to you promptly.

PROCESS EQUIPMENT DIVISION

U. S. STONEWARE
AKRON 9, OHIO

159-G

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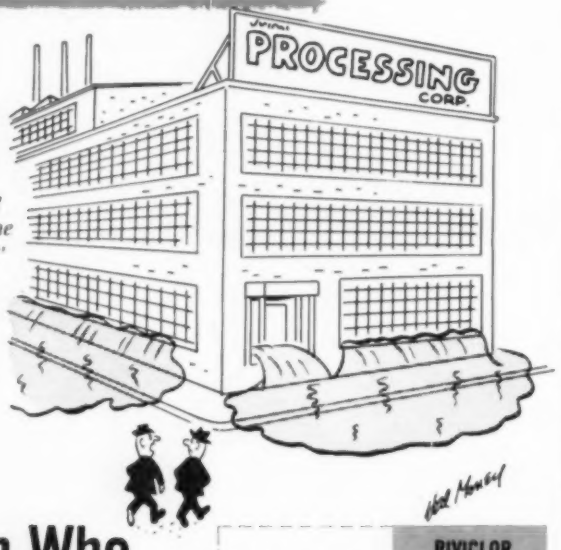
Life in these excited states...



"Sunday morning is no time to call me about a little leak"

For Men Who Work 24 Hours a Day

Like the phone ringing when you're in the shower, corrosion and contamination wait for no man. Best way to confine it to normal working hours is to specify trouble-free Ace chemical-resistant equipment by American Hard Rubber Company. Best for the money anywhere... backed by 108 years of experience.

All-purpose rigid PVC. Sched. 40, 80 & 120, ½ to 4". Threaded or socket-weld fittings. Valves ½ to 2". NSF-approved. *Bul. CE-56.*

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Improved design... now 12 gpm. All wetted parts acid-resistant, wear-resistant Ace hard rubber. Finest available. *Bul. CE-55.*

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Flexible poly pipe, ideal for water lines, drains, underground pipe or conduit. Sizes ½ to 2", long coils, NSF-approved for drinking water. *Bul. CE-57.*

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World's best chemical valves ... at moderate prices. All-plastic, rubber-lined, or all-hard-rubber. ⅛" pet cocks to 24" gate valves.

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ACE *chemical resistant equipment*
BY AMERICAN HARD RUBBER COMPANY
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See ACE equipment in Chemical Engineering Catalog

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industrial news

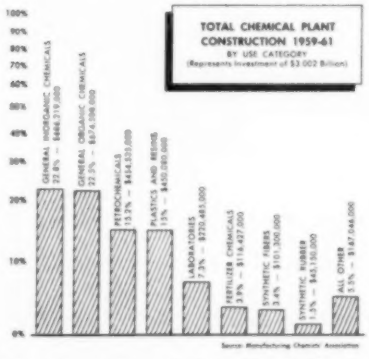
Chemical construction up $300,000

MCA Survey show new research and production facilities will cost over one billion and a half during 1960-61.

RESEARCH AND PRODUCTION FACILITIES slated for construction in 1960-61 in the chemical industry will reach a record high, according to the Manufacturing Chemists' Association. The annual survey shows that total cost will reach over a billion and a half dollars, with an increase in planned research facilities to a three year figure of $220.485 million for laboratory construction. This is a substantial rise over the $157.170 million listed for last year, and the $107.215 million the year before.

This collective price tag of $1.657 billion for projects to be built in the next two years, will bring the total construction costs in the industry for the three year period to an estimated $3.002 billion.

The continued upswing in announced expenditure for the construction of new laboratories is considered especially significant. Spokesmen for

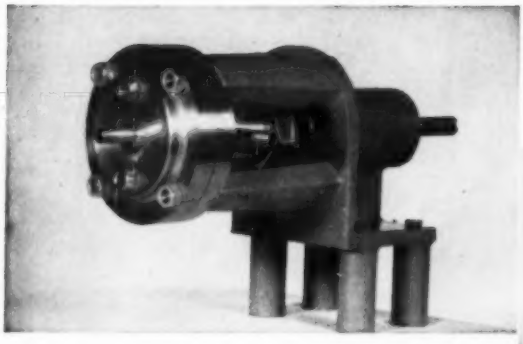


the chemical industry feel that increase in research facilities, and the new developments that will come from this, are an excellent barometer of the prospects for the industry as a whole since its continued growth depends to a great extent on new developments.

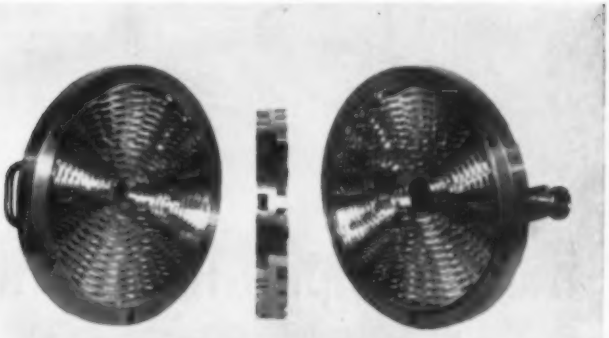
General organics and inorganics topped the MCA survey list of total

continued on page 92

NEW OAKES CONTINUOUS AUTOMATIC MIXER



Model 4MBH laboratory size mixer ready for drive mounting. Another model is available equipped with a direct variable speed power drive in three horsepower sizes.



Exploded view of Oakes mixer showing stationary end stator members and rotor. Material to be mixed is fed into center of rear stator and flows to the periphery of the mixer and then out of the center of the front stator.

For mixing any materials that will flow through pipes—gas, liquids, solids. Mixes materials thoroughly, with low power and with little heat generation. Available in sizes from laboratory and pilot plant up to large capacity production line models.

For the first time, a small size, continuous automatic mixer is available to the chemical industry. The Oakes mixer, used for years in the food and rubber industries, can now be applied to chemical industry processing problems to provide the economies that result from continuous mixing techniques.

The Oakes mixers are suitable for continuously mixing all materials and are especially adaptable to multiphase systems. Mixing is extremely thorough and rapid without damage and with little heating of the materials. Since only a small portion of material is being mixed at any one time, power requirements are low.

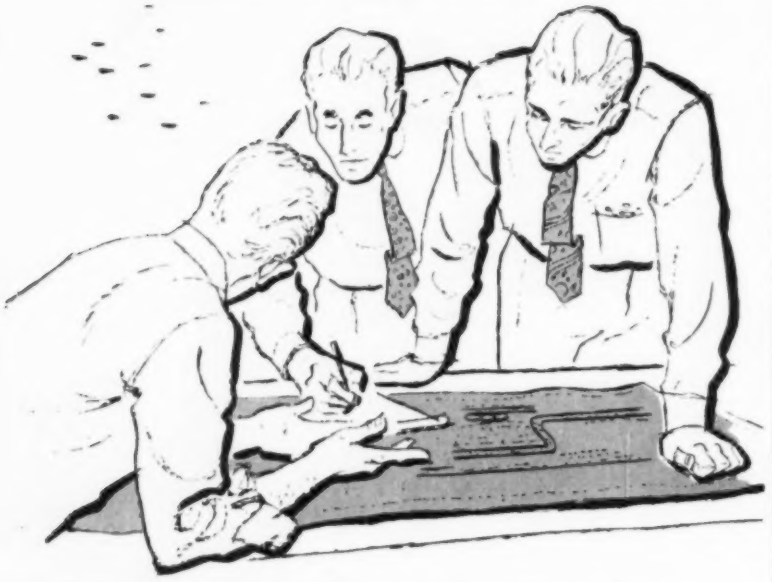
Oakes mixers are constructed of stainless steel, are exceptionally easy to open and clean and their simplicity of design makes them extremely trouble-free in operation. They are available in four models ranging from Model 4 for laboratories and pilot plants up to Model 14 for high quality production.

Catalog information is available upon request. To provide you with data that will be of greatest help to you, please give some indication of the materials you plan to mix and the quantities to be mixed per hour.

THE E. T. OAKES CORPORATION

26 COMMACK ROAD • ISLIP, LONG ISLAND, NEW YORK, U. S. A.

Considering PNEUMATIC CONVEYING?



Here's Helpful Information

If your company's processes involve the handling of materials that are dry, free flowing, pulverized, granular or pellet type, you'll find this bulletin interesting and informative. It describes SPENCER pneumatic conveying systems (stationary and portable) . . . contains diagrams of typical systems . . . illustrates representative applications . . . itemizes the advantages of conveying pneumatically.

REQUEST BULLETIN NO. 143-B.

The SPENCER TURBINE COMPANY
HARTFORD 6, CONNECTICUT

For more information, turn to Data Service card, circle No. 32

Construction

from page 90

construction (production as well as research facilities) with 202 and 179 construction projects, respectively. Other leaders in individual projects planned are plastics and resins, 128; laboratories, 108; petrochemicals, 35, and chemical fertilizer, 29.

On money to be expended for construction of facilities, general inorganic chemicals leads, with a total of $686.219 million. General organics, in first place last year, are second with $674 million, followed by petrochemicals with $454 million; plastics and resins, $450 million; laboratories, $220 million; fertilizer chemicals, $116 million; synthetic fibers, $101 million; special metals, $85 million; and synthetic rubber, $45 million.

A total of 290 projects are being carried out by 149 companies in 39 states. This can be compared to 216 in 33 states by 98 companies last year.

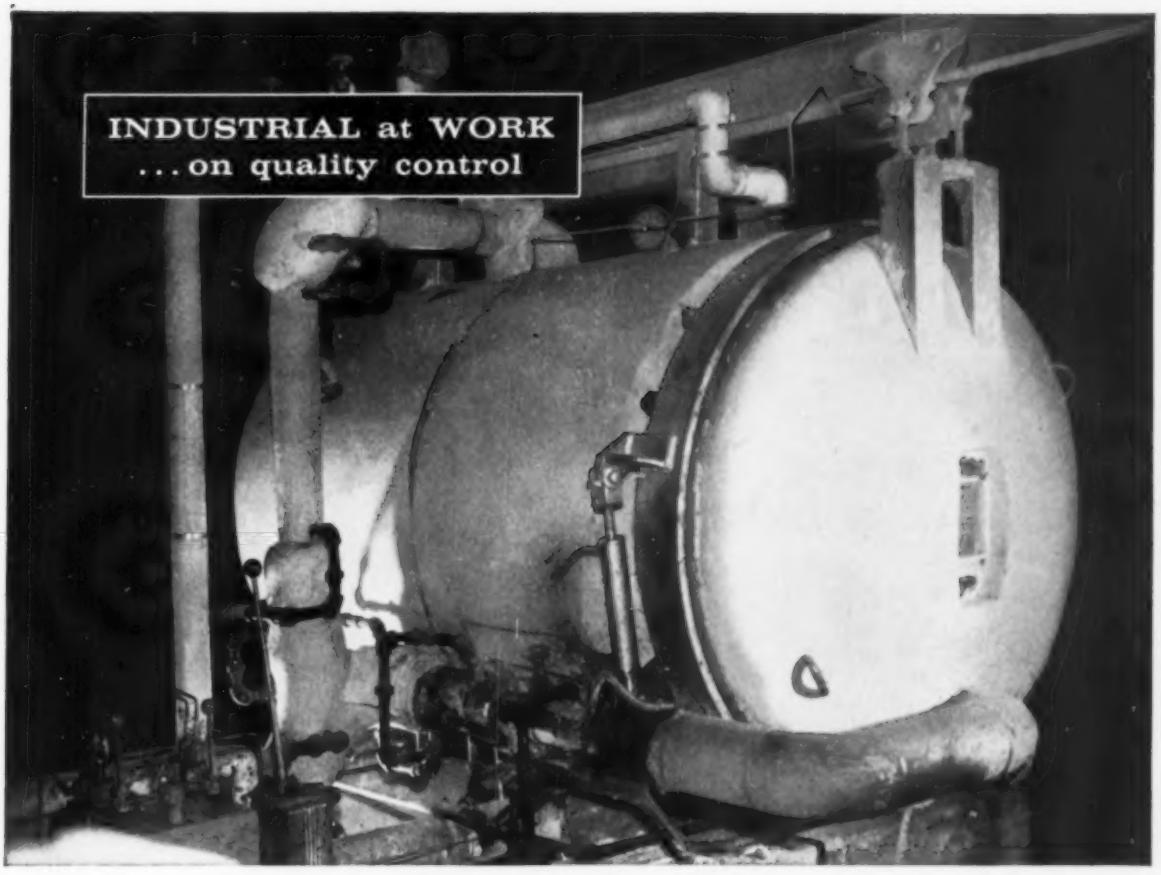
MCA's survey covers the chemical industry itself, and the construction of chemical producing facilities by firms identified primarily with other industries. This includes chemical process activities of all firms from which data is obtainable.

A subsidiary of Pennsalt Chemicals and Olin Mathieson Chemical, Penn-Olin Chemical, will produce sodium chlorate and other chlorate compounds. The newly organized firm will operate a 25,000 ton a year plant at Calvert City, Kentucky.

One of the largest propylene plants in the country, now in operation at Sun Oil's Marchus Hook refinery, is designed for a potential capacity of 120 million pounds a year. The production goes to AviSun for polypropylene resin, packaging films, fibers and molded products.

Another major increase in Dow's styrene monomer production capacity, this time at both the Dow Texas Division and the Midland Division, is expected to bring company capacity to more than 800 million pounds a year.

Thirty percent of the annual ammonia production of Tennessee Corporation's new unit goes to Southern Nitrogen, according to a signed agreement between the two. Tennessee's U. S. Phosphoric Products Division will build a multi-million dollar addition at its East Tampa, Florida, works. Southern Nitrogen plans to use the ammonia for processing nitrogen fertilizer products.



How STAUFFER CHEMICAL modernization pays off in improved sulphur quality

Improved sulphur quality and an increase in purification production were Stauffer Chemical's aims in a recent modernization program at their Chester, Pennsylvania operation.

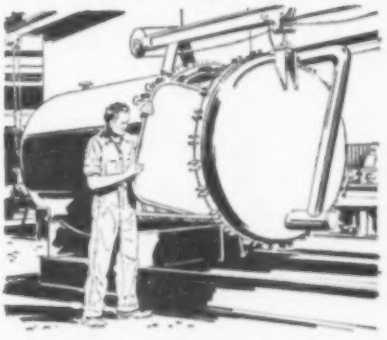
Playing an important role in these now realized goals was this type 122 *Industrial* horizontal filter. Here's how it helped Stauffer to:

IMPROVE QUALITY. Hand skimming of settled carbon from open troughs has been eliminated, permitting major improvements in quality control and optimum carbon removal through filter.

SPEED PURIFICATION. The Industrial filter is designed to handle both ash and carbon in one automatic operation. Raw sulphur is melted, purified and then pumped directly to processing.

In addition, the Industrial filter operation occupies *less* space because with settling eliminated—so is their need for tertiary tanks.

The Stauffer modernization story is typical of how quality-conscious processors throughout industry are turning to *Industrial*-engineered systems to help meet their customer requirements for more, but *better*, products . . . through controlled filtration.



Industrial's "lift out" leaves speed screen replacement and give easy access for filter maintenance. At Stauffer Chemical Company, extra-heavy bolted leaf construction and hydraulic leaf extractor automate operation.

WRITE FOR BULLETIN 122

INDUSTRIAL FILTER & PUMP MFG. CO.

5910 Ogden Avenue, Cicero 50, Illinois

INDUSTRIAL

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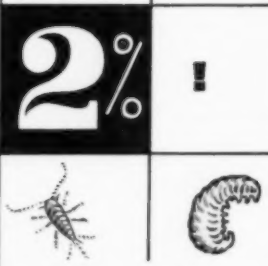
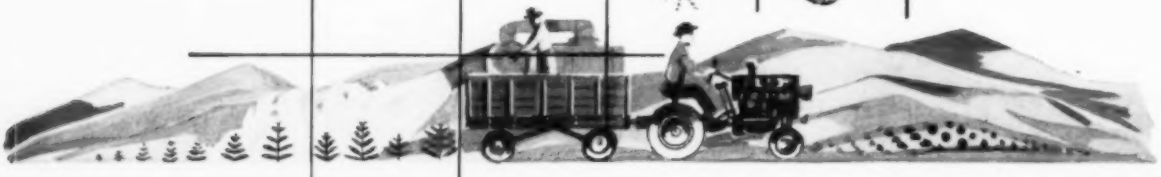
SULPHUR

ONE OF THE FOUR STRONG PILLARS OF PROCESSING

...BUT WHAT A 2% !





A recently compiled breakdown of Sulphur consumption in the United States, shows about 2% of the Sulphur goes into the manufacture of insecticides and fungicides.

Not much, perhaps, as tonnages go but no other use of Sulphur is more important with the possible exception of the 'wonder' drugs. It doesn't take much imagination to picture what would happen if the bugs and parasites were allowed to take over our crops and trees. Sulphur, along with other chemicals, is helping to protect our food supplies and foliage.

The role that TGS is playing in this constant fight against crop destruction is to see to it that the manufacturers of the insecticides and fungicides *always* have a ready supply of Sulphur, both solid and molten. This constant production and centralized distribution coupled with technical help is our contribution to industry.

SULPHUR PRODUCING UNITS

• Newgulf, Texas • Spindletop, Texas
• Moss Bluff, Texas • Fannett, Texas
• Worland, Wyoming
• Okotoks, Alberta, Canada

TEXAS GULF SULPHUR CO.

75 East 45th Street, New York 17, N.Y.
811 Rusk Avenue, Houston 2, Texas

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SUBJECT GUIDE to advertised product

EQUIPMENT

Agitators (p. 24). Bulletin 200 from Chemineer describes complete line of agitation equipment. **Circle 122.**

Analyzers, gas (p. 152). Analyze and record simultaneously from one to six constituents of a gas. Technical info from Cambridge Instrument. **Circle 59.**

Castings, high-alloy (p. 12). Technical info from Duraloy on shell molding for high alloy castings. **Circle 25.**

Compacting Process (p. 111). Can turn 80 to 90% of present waste fines into salable product. Bulletin 07B8836 from Allis-Chalmers. **Circle 38.**

Comparators (p. 143). Handbook (101 pages) from W. A. Taylor gives theory and application of pH control. **Circle 18.**

Compressors (p. 14). Data from Ingersoll-Rand on centrifugal, reciprocating, and "Axial-Flo" compressors, vacuum ejectors. **Circle 56.**

Computer, engineering (p. 81). Info from IBM on its Model 1620, suitable for statistical design of experiments, reactor design, mass spectrometry, kinetics. **Circle 101.**

Condenser, tower-type (p. 11). Data from Croll-Reynolds on the "Convactor," a combination of two condensers and a vacuum cooling chamber. **Circle 36.**

continued on page 96

MATERIALS

Chlorine and Caustic Soda (p. 113-114). Data from U. S. Industrial Chemicals on use in multi-stage bleaching of wood pulp. **Circle 110-1.**

Ethyl Alcohol (p. 113-114). Data from U. S. Industrial Chemicals on new ethyl alcohol production unit at Tuscola, Ill. **Circle 110-2.**

Gases, compressed (p. 115). Catalog from Matheson has prices and data on 85 compressed gases and mixtures. **Circle 85-1.**

Phosgene (p. 115). Detailed specifications and data on phosgene gas in Bulletin from Matheson. **Circle 85-3.**

Polyethylene (p. 113-114). Technical info from U. S. Industrial Chemicals on use for radiation shields. **Circle 110-4.**

Rust Solvent (p. 138). Info from Kano Laboratories on "Kroil" rust solvent. **Circle 3.**

Sodium (p. 113-114). Study results from U. S. Industrial Chemicals on sodium treatment of activated carbon. **Circle 110-3.**

Solvent, ethyl alcohol (p. 113-114). Data Sheet from U. S. Industrial Chemicals gives complete technical data on its new ethyl alcohol solvent, SOLOX. **Circle 110-5.**

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SERVICES

Atomic Energy Stock (p. 152). Prospectus from Atomic Development Mutual Fund on investment opportunities. **Circle 129.**

Corrosion Data (p. 137). Data from St. Martin's Press on newly-published book on "Corrosion and Oxidation of Metals." **Circle 17.**

Design and Construction, ethylene plants (p. 121). Technical info from Lummus. **Circle 131.**

Design and Construction, nitrogen removal plants (p. 87). Removal of nitrogen can upgrade natural gas, make profit on by-product. Info from American Air Liquide. **Circle 65.**

Design and Construction, process plants (p. 34). Info from M. W. Kellogg on design and construction services in U. S. and abroad. **Circle 41.**

Design and Construction, process plants (p. IBC). Data from Ralph M. Parsons on facilities for design, engineering, construction, economic studies. **Circle 78.**

Design and Construction, wax plants (p. 85). New Brochure from Badger gives details of large wax plant built for Atlantic Refining. **Circle 92.**

Fabrication, process equipment (p. 32-33). Brochure from C. H. Wheeler outlines advantages brought about by its merger with Griscom-Russell. **Circle 98.**

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EQUIPMENT *from page 95*

Conductivity Measurement (p. 130). Info from Industrial Instruments on new electrodeless method for measurement of electrolytic conductivity. **Circle 24.**

Control Systems, visual (p. 153). Booklet BE-30 from Graphic Systems. **Circle 87.**

Controllers, temperature (p. 119). Bulletins JSB and JG from West Instrument give complete technical details. **Circle 20.**

Conveyors, pneumatic (p. 92). Bulletin 143-B from Spencer Turbine gives diagrams of typical systems, representative applications. **Circle 32.**

Crystallizers (p. 27). Case history data in brochure "Processing Profiles" from Swenson Evaporator. **Circle 132.**

Cylinder Valve Outlets (p. 115). Bulletin from Matheson. **Circle 85-2.**

Density Gauges (p. 123). Bulletin 105-C from Ohmart Corp. gives detailed info on density control systems. **Circle 103.**

Detector, voids (p. 124). Finds pinholes and bare spots in thin-film protective coatings. Technical data and Bulletin from Tinker & Rasor. **Circle 30.**

Dryers (p. 26). Info from C. G. Sargent's Sons on design and engineering of dryers for all processing requirement. **Circle 60.**

Dryers, batch-type (p. 30). Complete Specification Bulletin from Despatch Oven. **Circle 40.**

Fans, Industrial (p. 18). Info from Garden City Fan & Blower on "Thermal-Aire" fans and plug units. **Circle 99.**

Filters (p. 25). Bulletin F-2049 from Eimco gives details of complete line of vacuum and pressure filters, gravity and flotation equipment. **Circle 62.**

Filters (p. 93). Bulletin 122 from Industrial Filter & Pump Mfg. **Circle 81.**

Filters, pressure, rotating leaf (p. 82). Details on the Valley rotating leaf pressure filter from Goslin-Birmingham. **Circle 121.**

Filters, vacuum, rotary-drum (p. 29). Info from Bird Machine on the "Bird-Young" filter. Multistage, countercurrent wash with sharp separation. **Circle 12.**

Flowmeter (p. 141). Info from Hetherington & Berner on the "Fluidometer" system, for use where meters must be located in hard-to-get-to places. **Circle 33.**

oject guide to advertised products and services

CLE CORRESPONDING NUMBERS ON DATA SERVICE CARD

Gas Generators, packaged (p. 139). For inert, CO_2, nitrogen, hydrogen, reducing and annealing gases. Data from Gas Atmospheres, Inc. **Circle 134.**

Heat Exchangers (p. 4). Bulletins on heat exchanger design from Downingtown Iron Works. **Circle 136.**

Heat Exchangers (p. 108). Design and engineering info from Aerofin. **Circle 123.**

Heat Exchangers (p. 120). In all grades of carbon, alloy, and stainless steels, nickel, aluminum, and special low-temperature materials. General Catalog from Engineers and Fabricators. **Circle 1.**

Heat Exchangers (p. 128). Info from Western Supply, Heat Exchanger Div. **Circle 19.**

Heat Exchangers, plate-type (p. 28). Info from Chester-Jensen on design and engineering of plate-type, other varieties of heat exchangers. **Circle 27.**

Heat Exchangers, sectional (p. 154). Bulletin 132 from Niagara Blower gives complete technical details of the "Aero" heat exchanger. **Circle 6.**

Heat Transfer Equipment (p. 127). Catalog 1652 from Young Radiator describes complete line. **Circle 4.**

Heaters, bayonet, tantalum (p. 79). Details from Fansteel Metallurgical. **Circle 83.**

Heating Systems (p. 142). Brochure 400 from Bethlehem Foundry and Machine describes completely-engineered systems for heating and cooling at high temperature levels. **Circle 133.**

Heating Units, induction (p. 126). Catalog from Lepel High Frequency Laboratories on high-frequency induction heating units. **Circle 96.**

Indicator, liquid-level, tanks (p. 139). For measurement of tank contents at any distance. Data from Uehling Instrument. **Circle 107.**

Irradiation Unit, gamma (p. 99). Data from Atomic Energy of Canada on the Gammacell 220, kilocurie cobalt-60, other isotope equipment. **Circle 102.**

Mills, cage (p. 136). Specially designed for wet, sticky, or gummy materials. Stedman Foundry & Machine. **Circle 97.**

Mill, hammer (p. 13). Bulletin 51-C-1 from Pulverizing Machinery on the "Mikro-Bud," able to process wide range of heat-sensitive materials without coolants. **Circle 16.**

Mixers (p. 125). Technical info from Gabb Special Products on the "Shear-Flow" mixer. **Circle 94.**

Mixers (p. OBC). Technical data from Mixing Equipment Co. **Circle 80.**

Mixer, continuous, automatic (p. 91). Catalog info from E. T. Oakes. **Circle 124.**

Mixers, mass and paste (p. 112). Available in sizes from 3 to 300 gal. capacity. Data from Paul O. Abbe. **Circle 10.**

Nozzles, spray (p. 130). Catalog 1 from Monarch Mfg. Works. **Circle 89.**

Nozzles, spray (p. 141). Comprehensive spray nozzle Catalog 5900 from Binks Mfg. **Circle 13.**

continued on page 98

MATERIALS *from page 95*

Sulfur (p. 94). Data from Texas Gulf Sulphur on use in insecticides and fungicides. **Circle 84.**

SERVICES *from page 95*

Fabrication, process equipment (p. 83). Data from Boardman Co. on facilities for design and fabrication of chemical processing equipment. **Circle 90.**

Fabrication, process equipment (p. 103). Info from General American Transportation on "Process Dynamics," new concept for evaluation and control of equipment and process performance. **Circle 14.**

Fabrication, process equipment (p. 135). Data from Chas. Ross & Son on mixing, grinding, and dispersing equipment. **Circle 53.**

Fabrication, process equipment (p. 129). Info from Edw. Renneburg on kilns, combustion equipment, calciners, collectors, evaporators, mixers, elevators, conveyors, etc. **Circle 91.**

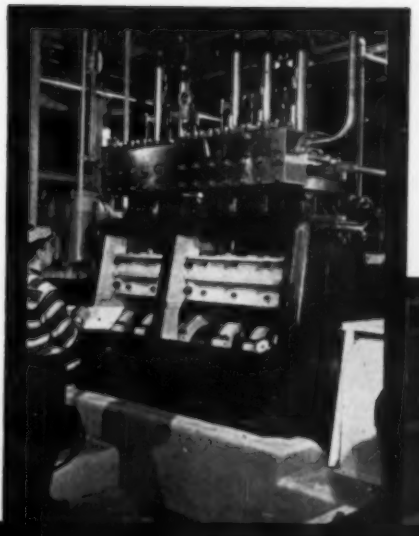
Fabrication, process equipment (p. 131). Intricate fabrication in stainless, aluminum, Monel, nickel, Inconel, all clad materials. Bulletin 550 from Koven Fabricators. **Circle 140.**

Isotope Research (p. 101). Info from General Motors Research Laboratories on recent work in rare earth isotopes. **Circle 2.**

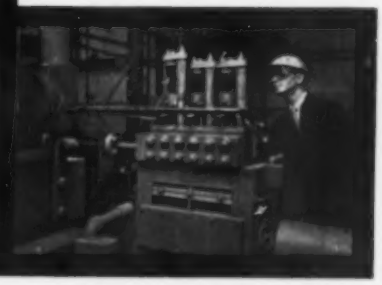
Technical Data Books (p. 140). Catalog from Lefax Publishers contains more than 2,000 listings. **Circle 15.**

Tower Packing Data (p. 88-89). More than fifty graphs show performance of various packings with data on capacity, efficiency. U. S. Stoneware. **Circle 26.**

WHAT'S YOUR SPECIAL PROBLEM IN PUMPING?



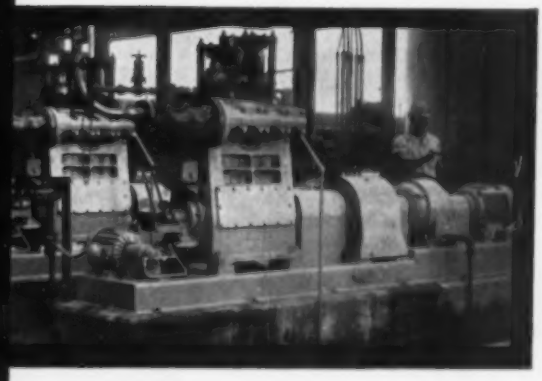
Special nylon ball valve and stainless steel fluid end handle silica gel at 1800 psi.

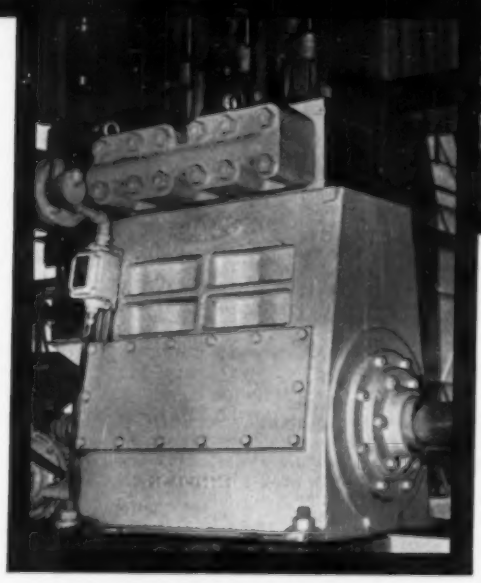


Here, Aldrich pumps continuously control the flow of liquid ammonia at 3700 psi.

This Aldrich pump handles highly corrosive chemicals—both alkaline and acidic.

Aldrich pumps with nickel alloy fluid end pump 50% caustic soda solution at 400 psi.





To handle, alternately, caustic and brine, at 3000 psi, this Aldrich Triplex pump has entire fluid end of Monel.

Corrosives? Slurries? High pressures? High temperatures? We'll find the answer!

All pump companies sell pumps. And all have their share of pumping problems. At Aldrich, our most important stock in trade is our ability to solve the rough pumping problems of the process industries. We've had over 50 years of working with chemicals and chemical processes. We know the problems of pump wear; of temperature, corrosion, viscosity; and your need for sustained pump operation. We study all the factors in your problem, in depth . . . and come up with a *better* answer, not merely *an* answer. For information on capacities, pressures and sizes, see our insert in *Chemical Engineering Catalog* or write for reprint (Data Sheet 100). ALDRICH PUMP COMPANY, 20 Gordon Street, Allentown, Penna.

The tough pumping problems go to **ALDRICH**

For more information, turn to Data Service card, circle No. 11

CEP'S DATA SERVICE—Subject guide to advertised products and services

CIRCLE CORRESPONDING NUMBERS ON DATA SERVICE CARD

EQUIPMENT *from page 96*

Packings, asbestos (p. 153). Bulletin from Greene, Tweed on "Palmetto" packings gives service conditions, applications, prices. **Circle 95.**

Piping, corrosion-resistant (p. 6-7). High temperature chemical resistance up to 500°F. Data from Resistoflex. **Circle 135.**

Piping, polyethylene (p. 90). Sizes ½ to 2 in. in long coils. Bulletin CE-57 from American Hard Rubber. **Circle 7-4.**

Piping, PVC (p. 90). Schedule 40, 80, & 120, ½ to 4 in. Valves ½ to 2 in. Bulletin CE-56 from American Hard Rubber. **Circle 7-1.**

Preheater, air (p. 109). Technical data from Air Preheater on the Ljungstrom continuous regenerative principle. **Circle 58.**

Processor, solids (p. 104-105). Data from Patterson-Kelley on its new Solids-Processor which adds vacuum drying to liquid-solids blending. **Circle 63.**

Pulverizers (p. 23). Info from Fluid Energy Processing & Equipment on the "Jet-O-Mizer," for simultaneous fine grinding, dehydration, coating, blending, chemical reaction. **Circle 37.**

Pulverizers (p. 128). Bulletin 091 from Sturtevant Mill gives details on the "Micronizer," available in 8 models, capacities from 1 to 4,000 lb./hour. **Circle 28.**

Pumps, canned (p. 117). Pressures to 5,000 lb./sq. in., temperatures to 1,000°F, capacities to 600 gal./min. Composite Bulletin 1100 from Chempump. **Circle 31.**

Pumps, corrosion-resistant (p. IFC). Heads to 345 ft., capacities to 3,500 gal./min., temperatures to 500°F. Data from Duriron. **Circle 93.**

Pumps, gear, corrosion-resistant (p. 90). All wetted parts in acid-resistant hard rubber. Bulletin CE-55 from American Hard Rubber. **Circle 7-2.**

Pumps, process (p. 97). Data Sheet 100 from Aldrich Pump gives info on capacities, pressures, sizes. **Circle 11.**

Pumps, regenerative turbine (p. 126). Technical Bulletin 105 from Roy E. Roth gives performance curves on all sizes. **Circle 82.**

Pumps, rotary gear (p. 136). New Bulletin G-1 from Schutte and Koerting gives full details on standard line. **Circle 35.**

Pumps, screw (p. 10). Bulletin 206 from Warren Pumps gives details of external gear and bearing screw pumps. **Circle 104.**

Pumps, small (p. 107). Info from Eco Engineering on rotary gear, and centrifugal types. **Circle 9.**

Pyrometer, surface (p. 138). Info from Illinois Testing Laboratories on the Alnor Type 2300 surface pyrometer. **Circle 5.**

Refrigeration Equipment, vacuum (p. 38). Technical data from Graham Mfg. **Circle 79.**

Rotameters (p. 110). Bulletin 18RG from Schutte and Koerting gives detailed instructions for liquid and gas sizing of its "Safeguard" model with PVC end fittings. **Circle 34.**

Rupture Discs (p. 135). Complete Catalog from Fike Metal Products gives details of rupture discs in sizes from 1 to 24 in., presures from 4 to 850 lb./sq. in. **Circle 54.**

DEVELOPMENT OF THE MONTH

ULTRASONIC FLOWMETER

(Circle 601 on Data Post Card).

A new ultrasonic flowmeter has been developed to measure the flow of liquids from outside a pipeline according to a joint announcement from Gulton Industries and Hersey-Sparling Meter Co.

The flowmeter operates by transmitting an intermittant sound wave from a transducer mounted on a standard pipe section. The flowing medium deflects the beam causing a sonic detector mounted externally on the opposite wall to detect a fraction of the input wave. A portable receiver unit would be calibrated to give instantaneous and total flows.

The flowmeter has been used on water lines and is reported applicable to the chemical process industries.

For more information from Gulton Industries, Circle 601 on Data Post Card.

Separators, entrainment (p. 18). Bulletin ME-9 from Metal Textile gives info on Metex knitted-wire entrainment separators. **Circle 57.**

Tanks (p. 137). Fabrication in all types, shapes, and sizes. New Catalog from Littleford Bros. **Circle 106.**

Tanks, Kettles (p. 152). In stainless, titanium, nickel, Monel, Inconel. Catalog info from Hubbert. **Circle 105.**

Tanks, rubber-lined (p. 120). Technical info from Gates Rubber. **Circle 120.**

Tanks, wood, polymer-lined (p. 143). Data from Wendnagel. **Circle 21.**

Transmitter, flow, low-rate (p. 36). Data from Foxboro on new Integral Orifice d/p Cell Transmitter for measurement and indication of flows as small as 0.003 gal./min. **Circle 55.**

Valves (p. 31). Three Technical Bulletins from Kieley & Mueller give details of split-body valves, level controllers, pressure regulators, diaphragm valves. **Circle 23.**

Valves, control (p. 9). Data from Annin on complete line. Body sizes from ¼ in. and up. **Circle 22.**

Valves, corrosion-resistant (p. 90). Plastic-, rubber-, or hard rubber-lined. Info from American Hard Rubber. **Circle 7-3.**

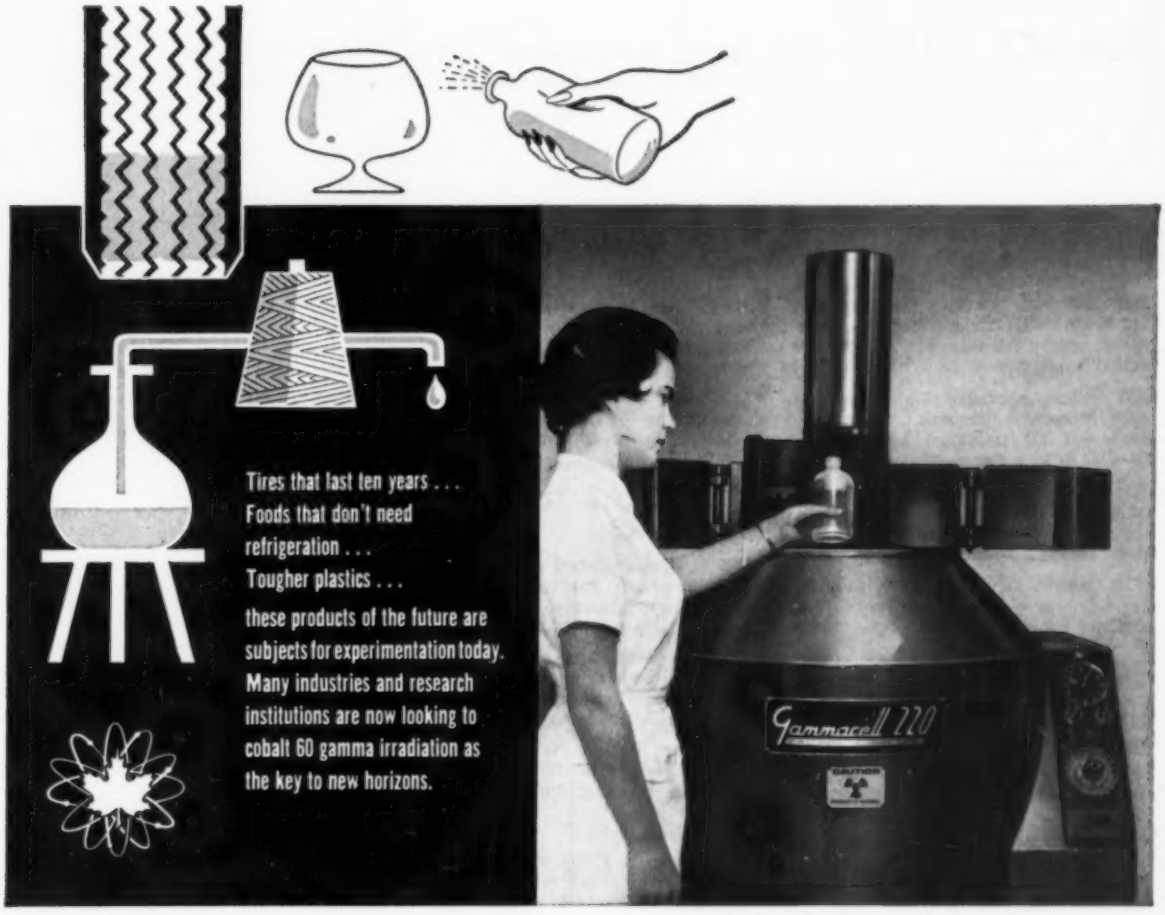
Valves, "Flo-Ball" (p. 19-22). Data from Hydromatics on new design ball valve, available in sizes from ⅛ to 24 in. **Circle 111.**

Valves, porcelain (p. 86). Catalog 567 from Lapp Insulator gives details of complete line in ½ to 6 in. sizes. **Circle 130.**

Valves, regulating (p. 140). Bulletin C-67C from Fisher Governor. **Circle 8.**

Water Treating Equipment (p. 140). Catalog from Hungerford & Terry describes complete plants for demineralization, dealkalizing, clarification, silica removal, etc. **Circle 29.**

Weighing Unit (p. 5). Catalog 101, "W-E" from B. F. Gump gives details of the Edtbauer-Duplex Net Weigher. **Circle 88.**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Foods that don't need refrigeration . . .
Tougher plastics . . .
these products of the future are subjects for experimentation today. Many industries and research institutions are now looking to cobalt 60 gamma irradiation as the key to new horizons.
Gammacell 220

Photo courtesy Textile Research Center, School of Textiles, North Carolina State College, Raleigh, N.C.

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with source strengths to suit your purpose

IT'S PROVEN — Already in use in several countries and in many fields of research.

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IT'S SAFE — By construction, it is inherently safe to operate. Overexposure would have to be deliberately planned.

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For more information, turn to Data Service card, circle No. 102

SUBJECT GUIDE to free technical literature

CIRCLE CORRESPONDING NUMBERS ON DATA SERVICE CARD

EQUIPMENT

301 Blender, rotary. Details from Sturtevant Mill Co. describes new, automatic, rotary blender and hopper for versatile plant use.

302 Boilers, packaged. Eight-page Catalog gives specifications, ratings, dimensions for packaged boilers from Cleaver-Brooks Co.

303 Collectors, sludge. Complete line of sludge collectors for water, sewage, industrial wastes from Link-Belt Co. described in 27-page Book.

304 Control, liquid level. Information for floatless electrode-type liquid level controls included in Catalog from Charles F. Warrick Co.

305 Controls, nuclear. Nuclear power controls and system instrumentation listed in folder from Consolidated Controls Corp.

306 Conveyors, Screw. New 76-page Book 2989 describes application, selection of screw conveyors, screw feeders and components. Book from Link-Belt Co.

307 Couplings, flexible. New 48-page Catalog presents technical data for complete line of flexible couplings from Thomas Flexible Coupling Co.

308 Detector. Specification Guide for electrical detector device for inspection of corrosion resistant coatings from Tinker & Rasor.

309 Detector, gas. Details for portable gas detector designed to give indication or alarm for unsafe gas concentrations from Houston Instrument Corp.

310 Dewars, helium storage. Specifications for liquid hydrogen/helium containers from Superior Air Products Co.

311 Equipment, air-conditioning and drying. New 16-page Brochure describes latest equipment from Midland-Ross Corp.

312 Equipment, drying. Information for new, simplified dryer for compressed air and other gases available from Pittsburgh Lectrodryer Div. (McGraw-Edison).

314 Equipment, dust control. New 28-page Bulletin No. 805 covers equipment for dust control and air pollution problems. Dracco Div. of Fuller Co.

315 Equipment, processing. Bulletin GP60 from Skinner Engine Co. describes production mixers, blenders, roller mills, colloid mills.

316 Fittings, tube. New 46-page Hi-Seal tube fittings Catalog from Imperial Brass Mfg. Co. gives dimensions and technical data.

317 Instrumentation. Gauges and instruments for the process industries described in Bulletin from U. S. Gauge.

continued on page 102

MATERIALS

356 Coatings, protective maintenance. New Brochure describes applications of coating systems for corrosion protection. Data from Gildden Co.

357 Cryogenic Fluids. Folding Pocket-Card containing physical, thermodynamic properties of cryogenic fluids and conversion factors from Linde Co.

358 Epoxy Resins. New 24-page Data Booklet describes three new epoxy resins having novel structure, reactivity, curing characteristics. Food Machinery and Chemical Corp.

359 Fillers and Filteraids. Fact sheet describes diatomite and perlite fillers and filter-aids from Dicalite Div. of Great Lakes Carbon Corp.

360 Gluconates. Data Sheet No. 549 from Chas. Pfizer & Co., Inc. describes advantages of adding gluconates to the caustic soda-aluminum etching solutions.

361 Materials. Technical Data Folder describes new materials resistant to corrosion, radiation, high temperatures, and abrasion from Carborundum Co.

362 Materials, electrical insulating. Complete line of insulating materials for electrical equipment described in Borchure from General Electric.

363 Packings. Revised Catalog and price list for Palmetto fabric, foil, plastic, and filament packings from Greene, Tweed & Co.

364 Polycarbonate Resin. Bulletin containing physical, electrical properties, and applications of new thermoplastic from Mobay Chemical Co.

365 Polypropylene. Technical Booklet presents data, properties, and bibliography on polypropylene. Booklet from Hercules Powder Co.

366 Resin, paint base. New 30-page technical Report on thermoplastic resin used as tough lacquer-type paint vehicle. Data from Marbon Chemical Div. of Borg-Warner.

367 Silicones. Eight-page 1960 Guide presents complete line of silicone products with uses and benefits. Data from General Electric.

368 Silicones, rubber. Data Sheet from Dow Corning presents properties of new room temperature vulcanizing silicone rubber.

369 Steel, data book. Pocket Guide designed to aide the engineer with the types and grades of stainless, alloy, and carbon steels available from Jones & Laughlin Steel Corp.

370 Steel, high strength. Fifteen-page Brochure from Universal-Cyclops Steel gives properties, data for ultra high strength steel.

371 Surfactant. New Product Bulletin from Onyx Oil & Chemical Co. contains specifications, properties, applications for new sodium lauryl ether sulfate surfactant.

SERVICES

372 Design and Construction. Information describing engineering, equipment, and construction service offered by Davidson-Kennedy Co.

373 Fabrication, silicone rubber. Bulletin describes custom molding service for silicone rubber parts from Tauton Div. of Haveg Industries.

374 Lubrication, centralized system. New 24-page Brochure describes equipment lubrication systems from Eaton Mfg. Co.

375 Periodic Table Chart. Complete periodic table of the elements in color offered by Atomic Development Mutual Fund.

376 Printing, polyethylene. Informative 15-page Booklet provides valuable material pertaining to printing on polyethylene surfaces. Data from U. S. Industrial Chemicals Co.

377 Processing, heat-sensitive products. Literature describes low temperature process based on heat pump principle for heat-sensitive products. Mojonnier Bros. Co.

378 Products and Services. Brochure describes complete line of products and services offered by Vitro Chemical Co.

379 Reference Book, isotopes. Revised 51-page Booklet lists 300 references to isotope literature with their availability. Bibliography from A.E.C.

For more information, circle No. 2

One of a series

Payoff in portable photons

Samarium-145, Samarium-153, Gadolinium-153.
Scientists at the General Motors Research Laboratories began three years ago to measure and re-evaluate the nuclear characteristics of these rare earth isotopes – their half-lives, photon emissions, thermal neutron cross sections.

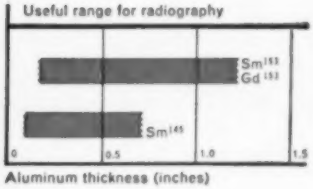
Conclusion: the radioisotopes had attractive possibilities in industrial and medical radiography, emitting almost pure gamma rays or X-rays (photons) in the low energy range of 30 to 100 kev.

The transition from research to hardware came through two key developments. First, cermet pellets were fabricated using only a few milligrams of the rare earth oxides. Then the irradiated pellets were packaged in special bullet-size holders.

The resulting small, sealed radiographic sources are now being field and laboratory tested. Two excellent applications: "inside-out" checks of hollow shapes inaccessible to X-ray tubes, and radiography of thin steel sections and low density materials such as aluminum or human bone. For example, a recent medical milestone was a chest radiograph of a living person made with a Sm^{153} source. The portable exposure unit to shield the source weighed only 18 pounds.

This isotope radiography program is but one example of the work underway in GM Research's modern isotope laboratory – work that means, through science, "more and better things for more people."

General Motors Research Laboratories
Warren, Michigan



Aluminum thickness (inches)

Sm^{153} exposure unit.

CEP'S DATA SERVICE—Subject guide to free technical literature

CIRCLE CORRESPONDING NUMBERS ON DATA SERVICE CARD

EQUIPMENT *from page 100*

318 Joint, expansion. Catalog 850 covers line of custom-made rubber expansion joints and flexible pipe from General Rubber Corp.

319 Joints, rotary. New precision type flanged rotary joints described in Data Sheets from Barco Mfg. Co.

320 Monitor, carbon dioxide. New gas stream monitor for continuous indication and control of less than 2% CO_2 in N_2 stream. Details from Industrial Instruments Eng.

321 Piston rings, Teflon. Information concerning applications for filled Teflon piston rings and rider rings from Garlock Packing Co.

322 Processor, solids. Information describing solids processor combining liquid-to-solids blending and vacuum drying from Patterson-Kelley Co.

323 Pumps. Bulletin from Fostoria Corp. describes Series C sealless, leakproof centrifugal pump for corrosive, toxic, radioactive fluids over wide range of temperature and pressure.

324 Pumps, centrifugal. Catalog from Eastern Industries gives details, sizes, performance characteristics, and specifications for line of centrifugal pumps.

325 Pumps, condensation. New Bulletin CP-600 including design features, specifications, engineering data for six basic condensation pumps from American Air Filter Co.

326 Pumps, metering. New 28-page Catalog 59 from Lapp Insulator Co. presents capacities, sizes, specs., uses, and detailed description of Pulsafeader metering pumps for industrial processes.

327 Pumps, sewage. Bulletin with performance table, dimensions, installation data for submersible sewage pump from Deming Co.

328 Pumps, slurry. Performance data, dimensions, and features of broad line of heavy-duty process pumps for handling slurry-type solutions from Goulds Pumps, Inc.

329 Pump, slurry. Bulletin 1158 describes diaphragm slurry pump for slurries with up to 60% solids, for flow volumes to 180 gal./hr., for pressures to 90 lb./sq. in. Data from Milton Roy Co.

330 Pumps, vertical. New line of vertical pumps described in Circular No. 219 from Dean Brothers Pumps Inc.

331 Reactors, glass-lined. Twelve-page Brochure describes new RA series glassteel reactors and accessories from Pfaudler.

332 Regulator, liquid oxygen. Information for new, high capacity, diaphragm-type pressure regulator from Bastian-Blessing Co.

333 Rotameters. New graphic rotameter Selector Aid from Brooks Rotameter Co. shows full line of meters with applications, advantages, and accessories.

334 Separator, centrifugal. Information for new multi-stage, push-type centrifugal separator for filtering variety of materials in chemical process industries offered by Baker Perkins Inc.

335 Separator, centrifugal. New nozzle-bowl centrifuge for high pressure and temperature separations offered by De-Laval Separator Co.

336 Speed Control. New Brochure describes and illustrates principles and applications of Varidyne a c. controlled speed systems. Details from U. S. Electrical Motors.

337 Speed Reducers. New 64-page Engineering Bulletin describes expanded line of speed reducers available from Dodge Mfg. Corp.

338 Thermocouples. New Brochure on metalic sheathed, hard packed, oxide insulated thermocouples and extension wire is available from Research Instruments, Inc.

339 Tubing. New 24-page Brochure describes uses for small diameter tubing, discusses platinum and precious metal products. Information from J. Bishop & Co.

340 Tubing, cupro-nickel. Technical Data Sheet gives uses, mechanical, physical, fabrication properties of 30% stronger cupro-nickel tube. Bridgeport Brass Co.

341 Tubing, polyethylene. Dimensions, properties, applications of polyethylene tubing described in Data Sheet from Parker-Hannifin Corp.

342 Tubing, Saran. Bulletin from Pyramid Plastics describes chemical resistant rod, sheet, tape, pipe, tubing, fittings made from Saran.

343 Tubing, stainless steel. New 34-page Booklet gives details on sizes, grades, design data, corrosion resistance, etc. for welded and seamless stainless steel tubing. Data from Allegheny Ludlum.

344 V-belt Drives. Thirty six-page Bulletin No. 9102 includes drive-selection tables, monograms for cost comparisons, sheaves and belt specs., horsepower tables, installation instructions. Info. from T. B. Wood's Sons Co.

345 Valve. Bulletin 257 from Autoclave Eng., Inc. gives information for new, compact tubing valve for pressures to 12,000 lb./sq. in.

346 Valve. Details from George W. Dahl Co. describes and illustrates compact ½-in. inline valve with high flow coefficient of 7.5 and pressure rating to 300 lb./sq. in.

347 Valve. Specifications for new type dump valve which provides positive leak-proof shut-off from APCO Div. of Textron.

348 Valves. Information and applications for new eccentric valves with Viton faced plugs for handling corrosive liquids, gases, slurries offered by DeZurik Corp.

349 Valves, ball. Information concerning applications, advantages, features of new line of ball valves from Hills-McCanna Co.

350 Valves, ball. Bulletin describes available Data Sheets for complete line of "double-seal" ball valves from Jamesbury Corp.

351 Valves, ball. Information describing new series of valves with ball mounted in fixed bearings available from Hydromatics, Inc.

352 Valves, pressure reducing. Details from Leslie Co. describes complete line of Hi-Flo liquid pressure reducing valves for closer control of water consumption.

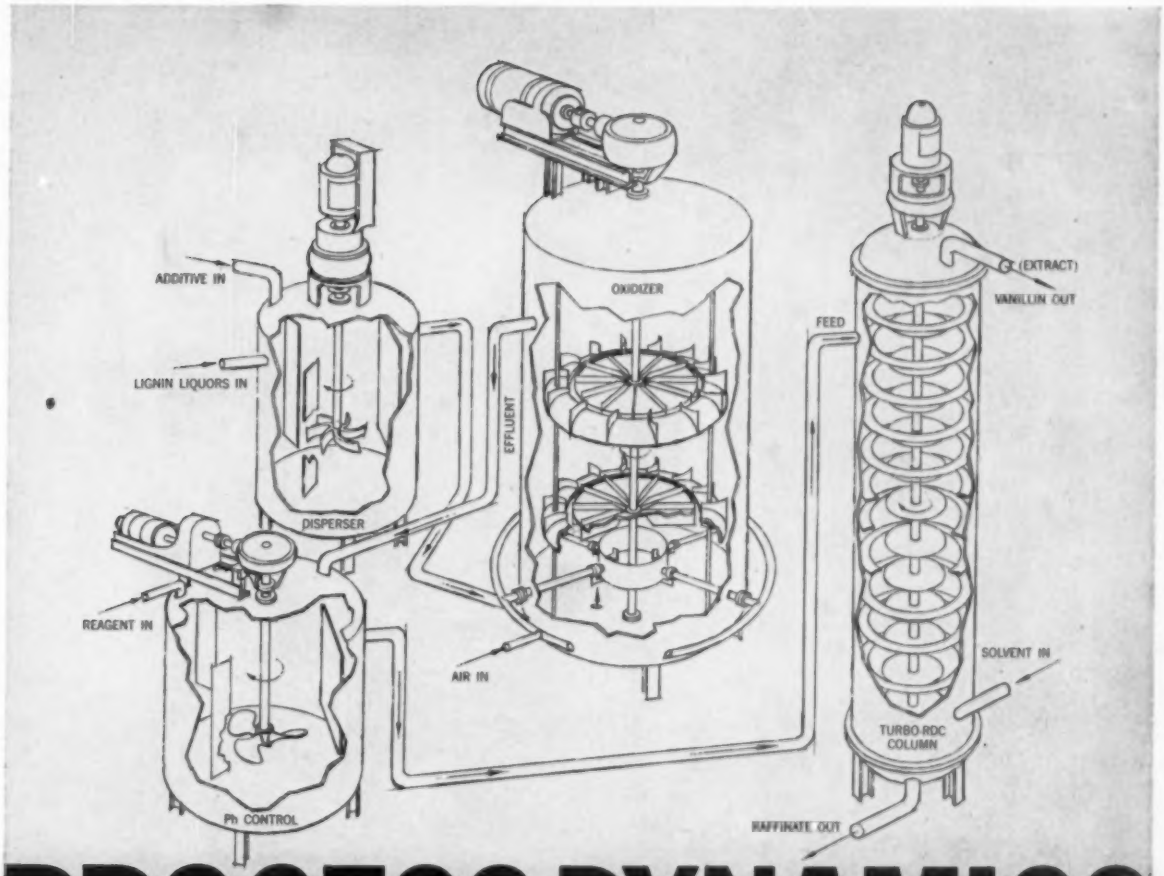
353 Valve, relief. Bulletin from Atlas Valve Co. describes regulating relief valve for oil or water service at initial pressures to 500 lb./sq. in. and temperatures to 250°F.

354 Valve, safety. Details for compact, high pressure, self-contained, high-low safety shut-off valve from Willis Oil Tool Co.

355 Valve, sampling. Information describing a sampling valve not affected by settlement or clogging from Strahman Valves, Inc.

A.I.Ch.E. Membership

Brochure—"Know Your Institute"—tells objective aim and benefits to chemical engineers who join this nation-wide organization, includes membership blank. Circle number 600 on Data Post Card.



PROCESS·DYNAMICS

A new concept for evaluation and control of **Equipment** and **Process Performance**

General American's wide diversification permits the design of equipment for *controlled performance* and *process in transport.* This diversification plus specialized experience and extensive laboratory facilities assures you of correct equipment construction and maximum utilization of automated systems.

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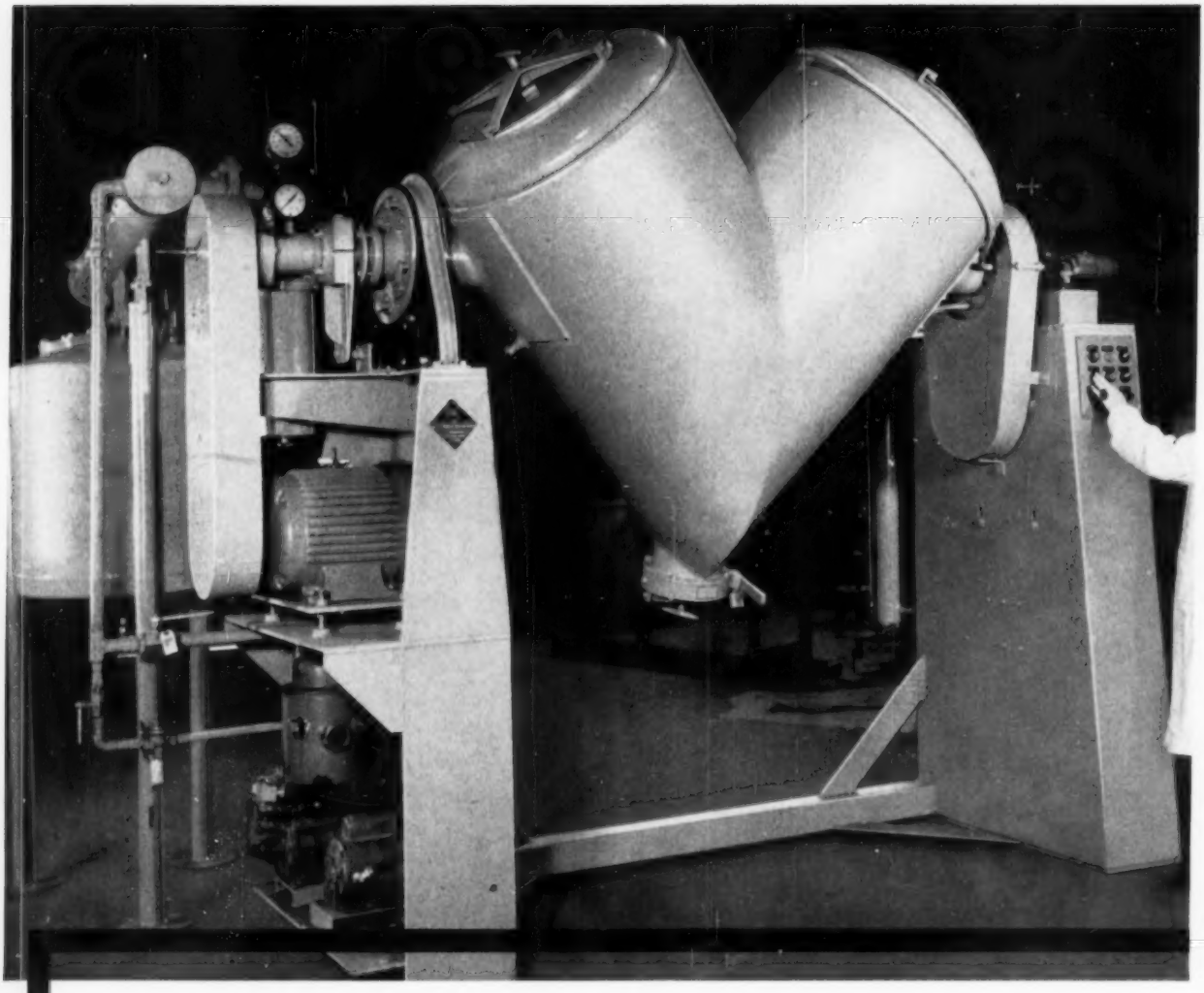


Now for the first time you can combine vacuum-drying and liquid-solids blending in a single packaged unit – the new P-K Solids-Processor. This latest P-K "Twin-Shell" development dry blends solids, disperses liquids, granulates and dries in simple sequence.

DRY BLENDING – Solids are tumbled to give gentle precision blending. This may be done under vacuum or atmospheric conditions, in inert or sterilizing gas, with heat in jacket up to 200° F., or with cooling water circulated through jacket. When needed, intensive blending breaks up agglomerates or gives uniform dispersion of pigments.

LIQUID DISPERSION, GRANULATING – Minute or large percentages of liquid are uniformly dispersed into solids. Dispersion can be sufficiently intimate to provide lump-free production. Or it can be regulated to produce granulations of controlled size. As in dry blending, these steps can be conducted under vacuum or atmospheric conditions, in inert or sterilizing gas, with heat in jacket up to 200° F., or with cooling water circulated through jacket.

DRYING – The new packaged system allows vacuum drying of heat sensitive materials with continuous turn-over and re-blending of solids. During drying, small balls with an insulating crust that inhibits complete drying tend to form. A separately actuated agitator breaks these up, permitting drying to a finished fine powder. In final stages of drying, direct hot air or gas can be introduced to reduce liquid content quickly to a fraction of a percent.

All P-K Solids-Processor systems are completely packaged. Available in standardized models with charge capacities from one to fifty cu. ft.

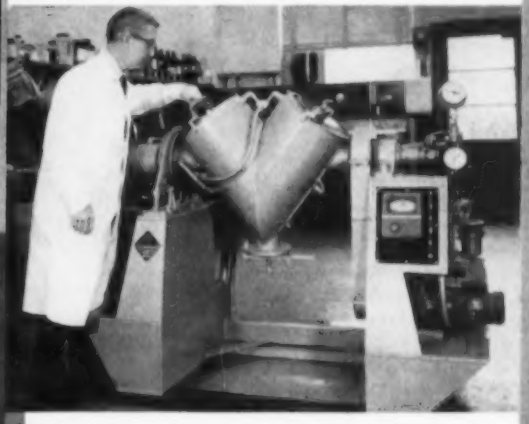
Revolutionary!

P-K Solids-Processor*

adds vacuum drying to liquid-solids blending...

Pre-test model available

We invite you to bring or send your materials to the P-K Pre-test Laboratory in East Stroudsburg. A one cu. ft. model of the new Solids-Processor is available for pre-testing . . . to demonstrate things impossible to see without pilot study . . . to work out subtle variables in blending, granulating and drying . . . to indicate accurately scale-up results and operational procedures . . . to predict savings in materials, labor and equipment investment.



Performs these operations:

1. Precision gentle blending
2. Intensive blending
3. Liquid dispersion in solids
4. Liquid-solids blending under vacuum
5. Granulation of solids
6. Dry blending under vacuum
7. Vacuum drying or cooling of solids
8. Heat sterilization of solids
9. Coating of solids
10. Chemical reaction under heat and vacuum
11. Direct gas drying

It's best if you can come yourself for pre-testing. You'll work with well-qualified engineers who have made thousands of resultful pre-tests for processors. They often suggest and produce unexpected product variations. Your guidance as to what is best for your product or process will be helpful. All you need is enough material for three separate one cu. ft. trial runs.

If you are unable to attend, send your materials. If possible, include a sample that will indicate optimum results. We'll give you a complete pre-test analysis.

Write or phone George Sweitzer collect at Stroudsburg, Hamilton 1-7500.

Patterson Kelley

Chemical and Process Equipment Division
115 Burson Street, East Stroudsburg, Pa.

*patented and patents pending

For more information, turn to Data Service card, circle No. 63

industrial focus

W. C. Philoon, E. F. Sanders, W. T. Trask, *Mallinckrodt Chemical Works, St. Charles, Mo.*

Uranium trioxide in a fluidized bed reactor

Development of a low-cost continuous process for production of a uniform uranium trioxide from purified uranyl nitrate solution.

Desirability of a continuous method for production of uranium trioxide is suggested by difficulties inherent in the present batch process. The material is heat sensitive during denitration, so that poor agitation and overheating may result in formation of large amounts of undesirable U_3O_8. Resulting batch-to-batch variations in the product are apparently responsible for a number of operating difficulties in subsequent steps. In addition, possible exposure of the operators to uranium oxide dust presents a formidable potential health problem. Work on development of a low-cost continuous process was done in the pilot plant of the Mallinckrodt Uranium Division under contract to AEC.

The fluidized bed technique was selected for several reasons:

- Highly turbulent mixing insures uniform temperature with consequent ease of temperature control;
- Good heat transfer and internal heating surfaces permit high production in economically-sized equipment;
- A free-flowing product of high bulk density suitable for subsequent process steps;
- A closed system with no moving parts minimizes possibility of personnel exposure to dust.

Equipment

The present reactor in the Mallinckrodt pilot plant (Figure 2) consists of a 10 in. diameter Type 347 stainless steel pipe, 6 ft. long, with a 20 in. diameter disengaging section located on top of the reactor and a fluidizing gas distribution plate flanged to the bottom. Thirty, 1¼ in. diameter bubble cap type distributors are provided in this plate with a 1 in. diameter bayonet heater passing through each bubble cap and extending 3 ft. into the reaction bed. Fluidizing air from the supply chamber below the distributor plate passes through the annular space between the bubble cap and the bayonet heater, and then into the reaction bed through three holes equally spaced around the riser just under the cap.

Heat is supplied to the reaction bed by molten heat transfer salt (45% sodium nitrite, 55% potassium nitrite) circulating through the bayonet heaters. The hot salt enters a supply chamber directly below the fluidizing gas chamber and passes through the annular space between the 1 in. diameter outer tube and the ¾ in. diameter inner tube, then returning through the inner tube and out the discharge chamber below the supply chamber.

Molten uranyl nitrate hydrate is sprayed into the reaction bed through

continued on page 108

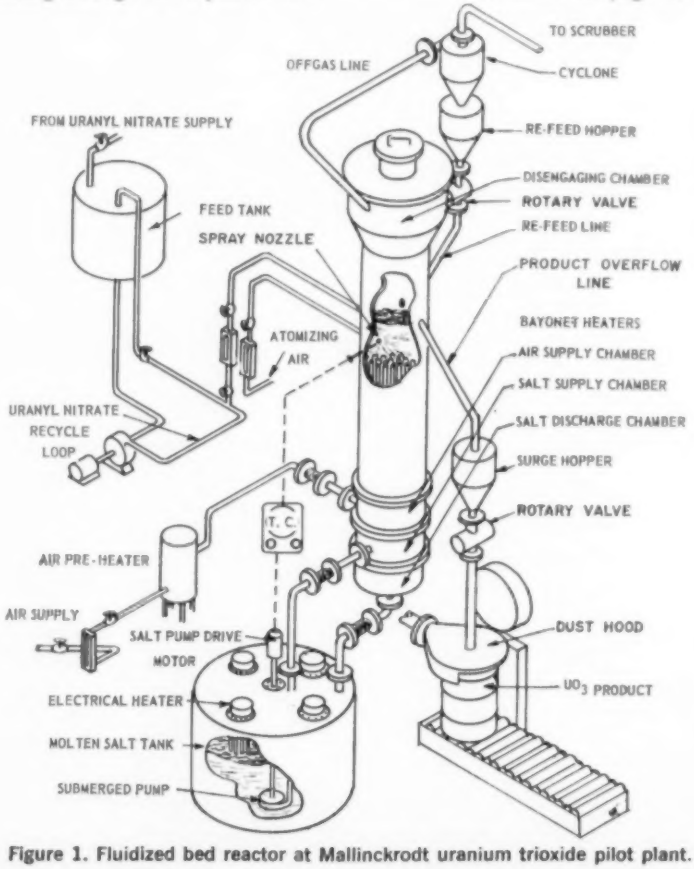


Figure 1. Fluidized bed reactor at Mallinckrodt uranium trioxide pilot plant.

For more information, circle No. 9 ➤

ECO ENGINEERING NEWS

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Pumping Notes

•

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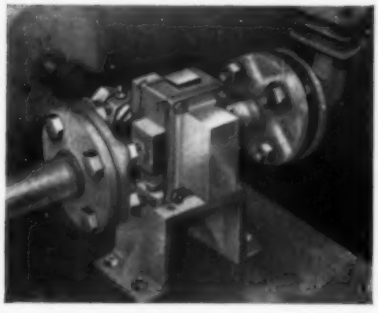

Eco GEARCHEM Pump, made of zirconium metal supplied by Carborundum Metals Company, is used in highly corrosive sludge pick-up service at a Carborundum plant. The environment is HCl (3N), H_2SO_4 (3N), H_2SO_4 (5N), methyl isobutyl ketone and 3 normal thio cyanic acid at ambient temperature.

Gears, bearings and packing are du Pont Teflon.

Get Complete Corrosion Data On Zirconium and Titanium

Are you sure that some of your most serious corrosive pumping problems, that stem from high temperatures, pressures and concentrations of reactants, cannot be solved readily with Eco Pumps made from one or the other of these atomic age metals?

A new 8-page Table which gives typical dynamic corrosion resistance values of zirconium and titanium, will help you find out. Write for your free copy.

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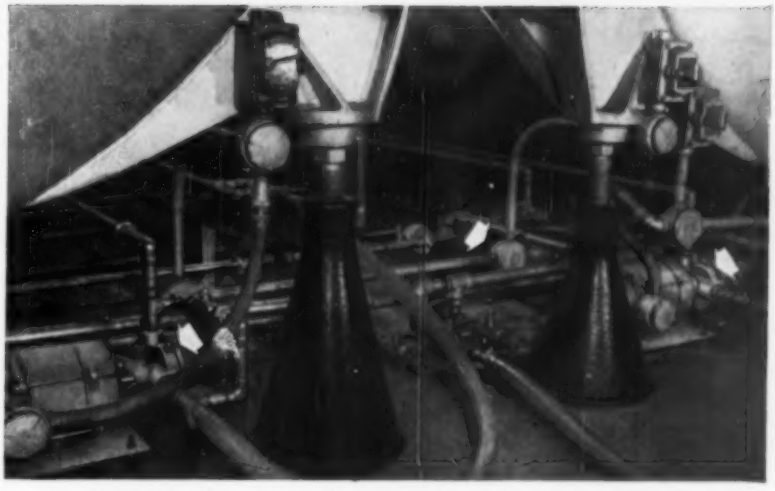


Eco CENTRI-CHEM Pumps under storage tanks at Nestle-Le Mur plant. Unique manifold arrangement permits pumping any desired product to various filling stations.

"Nothing Worked Until We Tried CENTRI-CHEM Pumps"

Nestle-Le Mur—originators of the "permanent wave" and producers of many hair beautifying products and other toiletries—had an extremely difficult pumping problem; transferring solvents in which certain gums were dissolved.

Packings Torn to Shreds

Pumps with conventional shaft packings were tried but, on intermittent operation, the gums solidified in the stuffing box when the pumps stopped and the packings were torn to shreds when the pump resumed operation.

Pumps with conventional mechanical seals also gave extremely short service life—at most, a few weeks, before becoming gummed up and inoperative.

Tried Centri-Chem Pumps

Finally the company tried Eco CENTRI-CHEM Pumps and the problem was solved. The rotary seal of these centrifugal pumps refused to gum up and the pumps are giving considerably better than a year's service without repairs of any sort.

Standardized on Centri-Chem

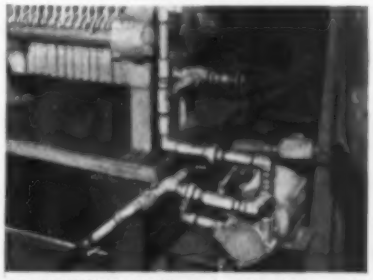
As a result, the company has standardized on Eco CENTRI-CHEM Pumps throughout the plant.

They are used for two principal services: First, product transfer from storage tanks to aerosol can filling machine lines where hair sprays are packaged. In some cases, these filling machines are as far as 300 feet from the storage tanks. Second, feeding filter presses which clarify the bottled products prior to packaging.

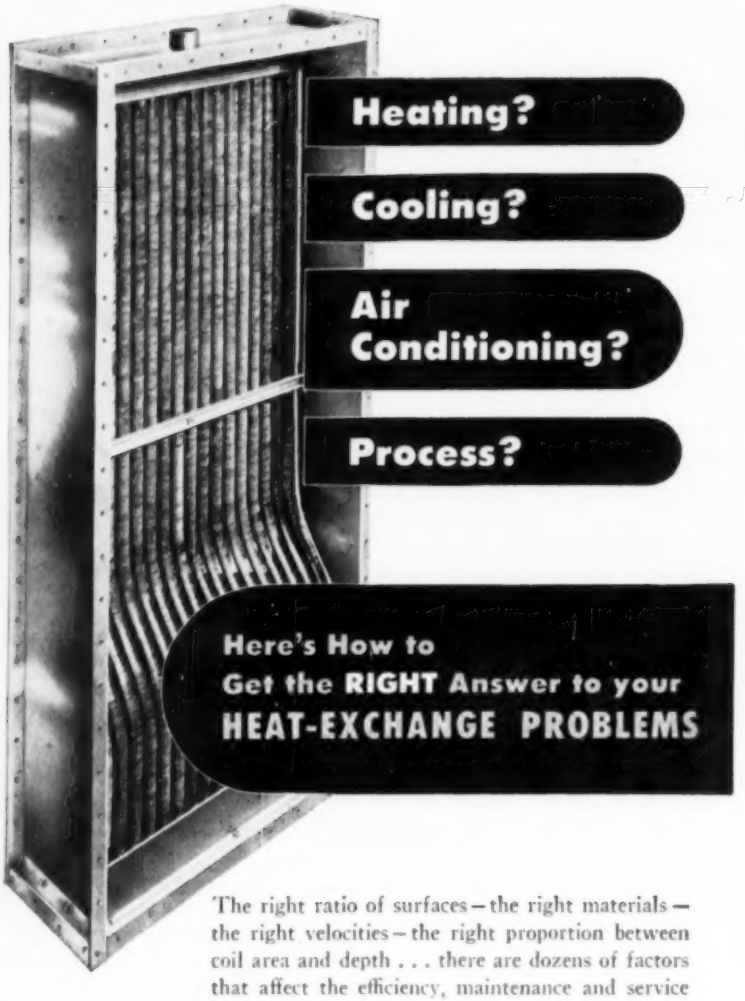
Keep Plant Going

Since both of these services are vital to continuous production lines, it is obvious what disruption to the entire plant's output would be caused by pump failure. Reason why Chief Engineer William Z. Nesin remarks, "life has been almost a pleasure since we installed our CENTRI-CHEM Pumps."

Close-up of one of the CENTRI-CHEM Pumps in product transfer service.



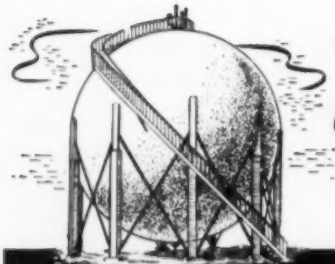
Eco CENTRI-CHEM Pump feeding filter press.



The right ratio of surfaces—the right materials—the right velocities—the right proportion between coil area and depth . . . there are dozens of factors that affect the efficiency, maintenance and service life of heat-exchange coils.

For best performance in your own application, the practical approach is to take full advantage of the unequalled engineering, research and design skill — the unequalled manufacturing and testing facilities — which Aerofin offers you.

To get the *right* answer—ask the Aerofin man.



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Uranium trioxide

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a two-fluid atomizing nozzle (Figure 3) mounted 6 in. above the tops of the heaters. The molten uranyl nitrate passes through the central orifice and is atomized by air flowing through the annular orifice. The nozzle is installed with the tip flush with the inside of the reactor wall.

Figure 1 shows the fluidized bed unit with its auxiliary equipment. Fluidizing air is metered through an electrical preheater to the gas distributor supply chamber. The molten uranyl nitrate is tapped from a recycle

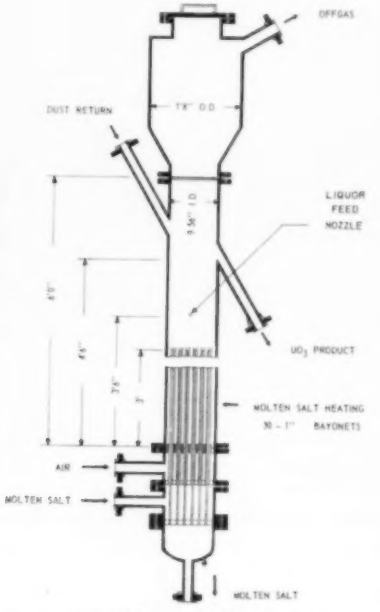


Figure 2. Fluid bed denitration unit.

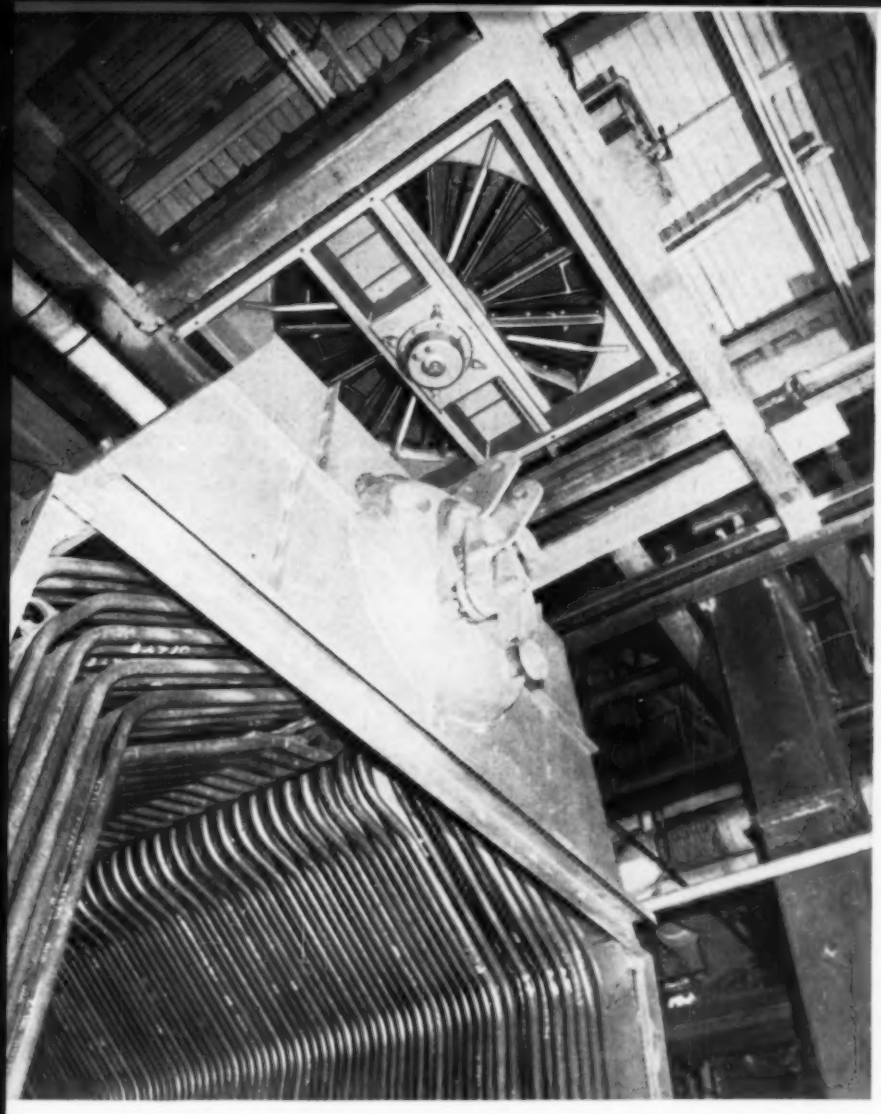
loop and metered through a rotameter to the spray nozzle. Air for atomization is also metered by a rotameter.

The heat transfer salt is heated by electrical immersion heaters in a large steel pot and pumped to the reactor by a vertically mounted, submerged centrifugal pump, driven by a 7.5 horsepower D.C. motor. The speed of the motor is controlled by the reactor temperature in the spray zone.

The UO_3 product overflows from the reactor through a 2 in. diameter pipe, 4½ ft. from the bottom of the bed, through a surge hopper and a rotary valve into a packaging station. The off-gases leave the reactor through a 2 in. pipe at the top of the disengaging section and pass through a cyclone separator to a scrubber; dust removed by the cyclone falls into a

continued on page 110

For more information, circle No. 58



The Ljungstrom Air Preheater at the B. F. Goodrich Company Shelton Plant is installed directly over the 65,000 lb/hr Wickes boiler. Flue gas leaving the boiler at 615° F passes through the circular rotor, which absorbs the heat and releases it into the incoming air. Preheated combustion air improves combustion, makes fuel burn cleanly. This Package Air Preheater was factory-assembled, and requird only 100 manhours to install.

At B. F. Goodrich Co.'s Shelton Plant

Air Preheater boosts combustion air temperature 345°F... gives 6% more thermal efficiency

"Only a Ljungstrom® Air Preheater, with its continuous regenerative principle, could meet our requirements", says A. G. Sandomirsky, Manager of Engineering at the B. F. Goodrich Company, Shelton, Conn., plant. "We produce foam rubber 24 hours a day, five and six days a week. With an Air Preheater we can meet process steam requirements more economically, and an Air Preheater helped us to justify the installation of high efficiency, high pressure equipment for by-product power generation."

Here's why the Shelton plant meets its requirements best with a Ljungstrom Air Preheater:

1. Ljungstrom is the most efficient heat exchanger you can buy. The Ljungstrom rotor revolves continuously through the flue gas and incoming air, thus absorbing heat and releasing it *from the same surface*. Since the heat doesn't have to pass through anything, each inch of rotor surface is as efficient as one foot of a tubular recuperator.

2. Ljungstrom is the most reliable heat exchanger you can buy. All heat exchange elements pass through the entire air and gas streams. The temperature of the elements in the coolest region — where fresh air enters — is actually an average of the gas and air temperatures, so it's consistently higher than the coolest point in a recuperative heat exchanger. Result: no cold spots, less chance of moisture formation.

3. Ljungstrom is easiest to maintain. You can inspect it — and clean it—while it's running. Heat exchange elements are divided into modular baskets that can be replaced individually without disturbing the other elements. You can even reverse the elements if the surface has thinned on one edge, effectively doubling the life of the heat exchange surface.

For more information on the Ljungstrom continuous regenerative principle, or on the Air Preheater that meets your requirements, phone MUrray Hill 2-8250 or write to The Air Preheater Corporation.

THE AIR PREHEATER CORPORATION

60 East 42nd Street, New York 17, N. Y.

SK "Safeguard" Rotameters with Polyvinyl Chloride (PVC) end fittings are now available for measuring the flow of hydrochloric acid, sulphuric acid, and the many other chemicals for which PVC is recommended. As a matter of fact, these new Rotameters are already being used for corrosive fluid service with excellent results.

Two facts regarding this new PVC "Safeguard" Rotameter are of particular importance.

First, this instrument provides a Rotameter with chemical resistant end fittings and rotor at much less cost than a similar instrument with these components made of other special corrosion resistant materials.

Second, the Fig. 18275 "PVC" Rotameter incorporates all of the features of the SK "Safeguard" line—one piece fabricated steel case, tube and rotor versatility, heavy safety glass windows, adaptability to panel mounting and to electric or pneumatic transmission for remote recording and controlling of fluid flow, and others.

New Bulletin 18RG describes SK's line of "Safeguard" Rotameters and gives detailed instructions for liquid and gas sizing. A special sheet lists fluids for which PVC is recommended. Send for your copy.

QUICK DELIVERY FROM STOCK

For Immediate Delivery, Standard SK Jet Ejectors, Rotameters, and Flow Indicators are stocked in Cornwells Heights (Phila.), Pa., Houston, Texas, and San Francisco, Calif.

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For more information, turn to Data Service card, circle No. 34

Uranium trioxide

from page 108

hopper whence it returns to the reactor through a rotary valve.

Operating conditions

The reactor has been operated at temperatures ranging from 600 to 800°F. Operation below 600°F was prevented by condensation of the reaction gases in the off-gas piping, and by wet powder plugging the fines refeed system. Operation at temperatures above 800°F restricted the capacity of the unit since, for safety reasons, the temperature of the heat transfer salt was limited to 1,000°F. Fluidizing medium was preheated air at flow rates ranging from 16.5 to 20 SCF/min. Flow rate was varied with bed temperature to maintain a constant gas velocity at the bottom of the reactor.

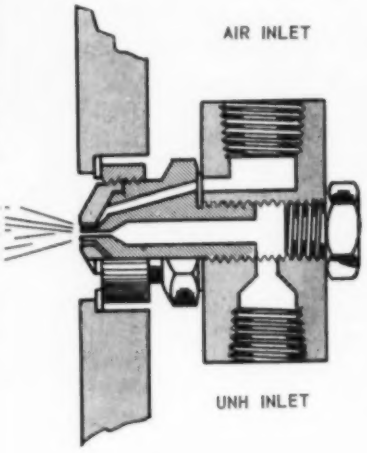

Figure 3. Detail of atomizing feed nozzle.

Uranyl nitrate was fed to the reactor in concentrations ranging from 5 lb. uranium/gal. to the molten uranyl nitrate trihydrate containing approximately 12 lb. uranium/gal.

A single atomizing nozzle was used to introduce the feed liquor into the reaction bed. Liquid feed rate through the nozzle was varied between 6 and 13.5 gal./hour with atomizing air flows ranging from 0.8 to 3.6 standard CFM at 10 to 60 lb./sq. in. gauge.

Production rates

Production rates of 50 to 150 lb. UO_3/hour have been attained; the lower rates with dilute aqueous feed concentrations and the higher rates

continued on page 112

For more information, circle No. 38 ➤

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The Allis-Chalmers compacting process can turn 80 to 90% of your present waste fines into salable granules . . . often of higher quality than the granules produced in your original process. For example: Tests on products reconstituted by the Allis-Chalmers system have shown compacted granules to have better controlled solubility, more uniform particle size, better "eye-appeal" and freer flow.

Here's how fines are recovered: Waste or fine salts from the original process are fed into a compacting mill. The mill mechanically densifies the fines into flakes. Flakes are then granulated by a roller mill—separated and sized by a vibrating screen.

For more information, get Bulletin 07B8836 from your A-C representative or write Allis-Chalmers, Industrial Equipment Division, Milwaukee 1, Wisconsin.

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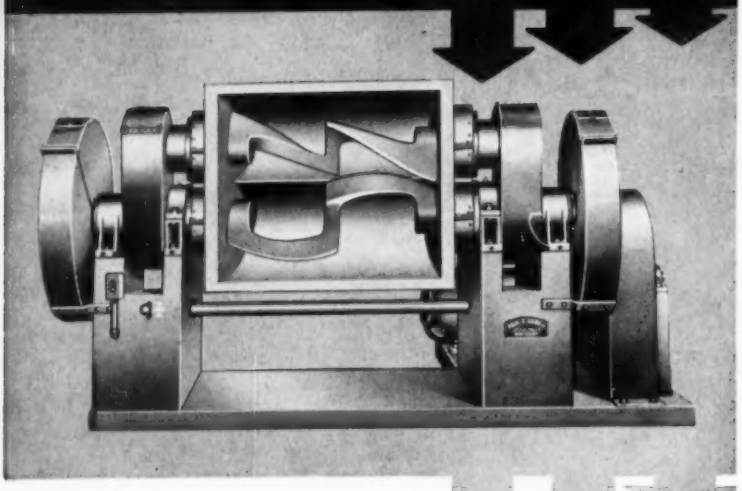
new mass & paste mixers



reduce maintenance, assure freedom from contamination.

The new rugged Paul O. Abbé Mass and Paste Mixers are built to give dependable trouble-free service. Heavy-duty antifriction bearings, mounted outboard in precision machined housings, assure perfect alignment of agitator shafts, thereby eliminating the main source of packing gland trouble.

A double end drive, through highly efficient spur gearing, distributes wear on gear teeth thus equalizing running strains and lengthening the life of the gears. Specially designed gear guards keep lubricant in and dirt out. Massive construction eliminates fatigue producing vibration.

Improved seals, easily accessible for maintenance, assure freedom from contamination.

These, and other design features, assure maximum output of finished product per dollar invested.

Made in a range of sizes from 3 to 300 gallons capacity, the mixer illustrated has a mixing volume of 150 gallons.

These improved mixers are available in various materials of construction. Jackets for heating and cooling can be installed around the mixer bowl, if desired. Various styles of mixer blades can be furnished to ensure the most effective mixing and blending of a wide variety of materials.

Write today for additional information.

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BALL & PEBBLE MILLS • DRY & PASTE MIXERS • DRYERS & BLENDERS

For more information, turn to Data Service card, circle No. 10

Uranium trioxide

from page 110

with the molten uranyl nitrate hydrates. At rates higher than 150 lb./hour, quantities of uranyl nitrate were carried out of the reaction bed, which resulted in clogging of the off-gas system.

Results

The uranium trioxide product was a free-flowing granular material made up of essentially spherical particles. Assay of the product averaged 99.0% UO_3, with residual nitrate and water content consistently less than 1%. There was no evidence of formation of the intermediate oxide, U_3O_8, in any of the runs.

Operating conditions had a pronounced effect on the particle size of the product. Average particle size at 700°F was 2½ times greater than at 600°F. At 800°F, average particle size continued to increase until loss of fluidization occurred. It is postulated that, since at a given superficial fluidizing velocity there is a higher bed void fraction at higher temperature, there are fewer solid particles on which the liquid droplets may collect, thus causing more rapid growth and hence larger particles.

As the ratio of the volume of atomizing air to volume of liquid feed through the nozzle is decreased, the average particle size of the product increases; this suggests that the particle size is related to degree of atomization at the nozzle. Both the feed liquor concentration and flow rate also seem to affect the particle size of the product, probably because they affect the volume of gas generated and hence the quality of fluidization in the spray zone. Data suggest that increased turbulence and attrition occurring at the higher gas flows result in a smaller average particle size in the product.

The product had a high bulk density, ranging from 3.5 to 4.3 gm./cc., depending on the production rate. Higher rates and/or feed concentrations may result in increased voids within the particles and consequently a lower bulk density. Particle size distributions were almost identical at different production rates in a number of cases, indicating that distribution is not a factor in the bulk density change.

Heat input to the fluidized bed ranged from approximately 72,000 to 160,000 Btu/hour. It is indicated that the heat transfer improves with increasing production rate.

For more information, circle No. 110

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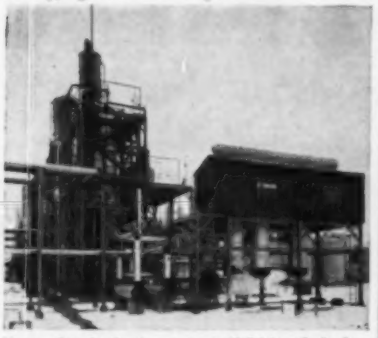
U.S.I. CHEMICAL NEWS

April ★ A Series for Chemists and Executives of the Solvents and Chemical Consuming Industries ★ 1960

New Ether Hydration Unit Ups U.S.I.'s Potential Ethyl Alcohol Capacity

A new ether hydration unit has just been completed at U.S.I.'s ethyl alcohol plant, Tuscola, Ill. With the new unit it is now possible for the company to take part of its ethyl ether production, formed as a by-product of the ethyl alcohol production process, and convert it to ethyl alcohol. The new unit gives the company an additional potential capacity of up to 6,000,000 gallons of ethyl alcohol annually, figured on a 190 proof basis.



New ether hydration unit at U.S.I.'s ethyl alcohol plant, Tuscola, Illinois.

U.S.I. refines a portion of the by-product ether to U.S.P., A.C.S., Refined and Technical grades for industrial, institutional and laboratory use. Part of the remaining material can now be converted into a low-proof ethyl alcohol through a catalytic process developed by U.S.I. The low-proof alcohol is then introduced into the regular process stream at U.S.I.'s alcohol plant for conversion to 190 proof or anhydrous product.

The new ether hydration unit enables U.S.I. to have a flexible means of keeping alcohol and ether production in balance. The company can serve the needs of these markets without being restricted by facilities.

Sodium Treatment Found to Increase Carbon Activity

A recent study reveals that sodium treatment of activated carbon, which is known to increase the material's ability to adsorb inert gases, also improves its liquid adsorption characteristics.

For the binary mixture n-heptane with toluene for example, toluene adsorption is increased from 48% to 58%. For n-heptane with propyl sulfide, adsorption of the latter material climbs from 25% to 85%.

The activated carbon is treated by stirring it with molten sodium until a homogeneous mixture is formed. Selectivity of the carbon is not altered.

The research group believes that sodium treatment causes small gaps to form between the carbon sheets which are generally thought to make up the structure of activated carbon. These gaps, probably made by sodium atoms wedging between the carbon sheets, give the carbon structure a honeycomb appearance. A much larger surface is thereby produced for liquid or gas adsorption.

U.S.I. Pulp and Paper Lab Expands to Cover More Bleaching Problems

Technical Service Work Now Emphasizes Use of Chlorine and Caustic Soda in Multi-Stage Bleaching of Kraft. Studies on Sodium Peroxide Bleaching Continue.

U.S.I.'s pulp and paper laboratory at Ashtabula, Ohio, established over eight years ago to provide technical service assistance on pulp bleaching with U.S.I.'s sodium peroxide, has been expanded, with the staff now working on problems relating to the use of U.S.I. chlorine and caustic soda in the multi-stage bleaching of wood pulp.

These technical service facilities are typical of the best industry laboratories maintained by pulp and paper companies themselves. Therefore, U.S.I. is able and willing to handle requests for comprehensive evaluations and recommendations on bleaching systems, techniques and chemicals—usually aimed at achieving the brightest pulp with the minimum degradation in fiber strength.

How Pulp & Paper Lab Functions

In a typical call, W. F. Schroeder, who has a very extensive background and acquaintance with the paper trade, visits a mill, examines the bleaching operation and takes pulp samples back to the laboratory.

MORE

Chlorination of kraft pulp on a laboratory scale in fume hood at U.S.I.'s pulp and paper lab, Ashtabula, Ohio. W. H. Schroeder has obtained a sample of filtrate for residual chlorine analysis. J. R. Leidich is checking weight of chlorine added to pulp.

Polyurethane Foam Radome, First Ever Built, Now Under Test in Canada

In a program designed to provide ground shelters with greater dielectric "transparency" —to minimize energy loss and boresight error in radar tracking installations—the world's first polyurethane foam radome has been built and is under test by Canada's National Research Council.

The polyurethane dome is undergoing an extensive series of electronic tests using actual field radar equipment. From these electrical analyses, NRC expects to obtain data indicating the suitability of such foam for radar at the frequencies involved. Favorable results could lead to extensive use of such foam, particularly for missile tracking in anti-missile type radar systems.

April ★ **U.S.I. CHEMICAL NEWS** ★ 1960

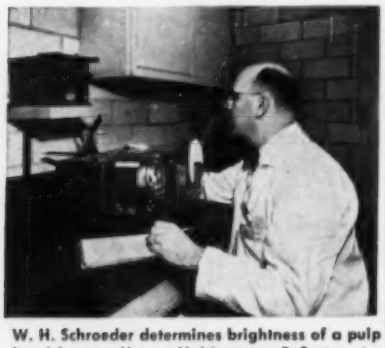
CONTINUED

Paper Laboratory

There the samples are bleached under a variety of conditions in a trial program based on knowledge of individual requirements and experience with many types of pulps. The bleached pulp samples are then made into hand sheets and tested for brightness and other necessary characteristics in a constant temperature, constant humidity testing room. Heat-aging studies can also be conducted. After all variables have been examined, a process is recommended for obtaining a bleached pulp that combines maximum brightness with maximum strength.

In the multi-stage bleaching of kraft—which usually involves treatment with chlorine, followed by caustic extraction and several whitening stages using bleaching agents such as hypochlorite, peroxide or chlorine dioxide—conditions of time, temperature, pH and pulp and chemical concentrations must be carefully worked out. U.S.I. technical service engineers are qualified to evaluate all the variables, including the type of equipment used.

U.S.I. interest in pulp bleaching arises from its sodium peroxide plant at Ashtabula, Ohio, and its two chlorine and caustic soda plants at Huntsville, Alabama. Further information on the pulp and paper technical service laboratory may be obtained by writing to U.S.I., 99 Park Avenue, New York 16, N. Y.



W. H. Schroeder determines brightness of a pulp handsheet on Hunter Multipurpose Reflectometer at U.S.I.'s pulp and paper laboratory.

Polyethylene Is Used For Radiation Shields

Polyethylene radiation shields, so thick they must be cut by specially designed saws, are being produced for use on atomic powered vessels. These polyethylene panels are intended to provide excellent protection from neutron bombardment and are lower in weight than conventional materials such as concrete and lead. The hydrogen nuclei in the polyethylene serve successfully to reduce the energy in the high energy neutrons created by atomic fission. A small quantity (1 or 2%) of boron, compounded with the polyethylene, absorbs the remaining low energy neutrons.

The polyethylene panels must meet rigid specifications and require critical quality control. They are made by a specially adapted extrusion technique which allows production of heavy gauge sheets. The shields can be made in standard widths over 36 inches and may be cut to any length according to specifications.

PETROTHENE® 100, a polyethylene resin supplied by U.S.I., is used to make the panels because of its ideal processing characteristics and because it passes all military specifications for radiation shielding.

Solox® Solvent Covered In New U.S.I. Data Sheet

Complete technical data on U.S.I.'s ethyl alcohol proprietary solvent SOLOX are given in a new, six-page data sheet. SOLOX frequently can be used in place of specially denatured alcohols because of its general utility and excellent solvent qualities. The permit and bond required for S. D. alcohols are not needed for SOLOX. It is noncorrosive, burns with a clean, colorless flame, leaves no residue and has a mild, nonresidual odor.

The new data sheet includes specifications, properties, compositions of the five SOLOX proprietory solvent formulations, and shipping information. Applications in lacquers, shellacs and varnishes, in the textile field, in chemical manufacturing, in cleaning compounds, as a fuel oil conditioner, in photography and as a fuel are described.

Government regulations pertaining to SOLOX complete the data sheet. Copies may be obtained from U.S.I. sales offices or from the New York office at 99 Park Avenue.

TECHNICAL DEVELOPMENTS

Information about manufacturers of these items may be obtained by writing U.S.I.

Protective coating systems for concrete floors compared in new coating chart. Gives resistance of each system to chemicals, thermal shock, abrasion, temperature. Shows compressive strength, impact resistance, skid properties. **No. 1580**

Silicone products for antifoams, release agents, lubricants, cosmetics, polishes, water, repellents, paints, textile finishes and electrical insulation described in new bulletin. Silicone rubber compounds also covered. **No. 1581**

New hydrogen analyzer uses hot extraction principle to determine content of the gas in metals. Said to be compact, inexpensive, and to combine speed and accuracy with ease of operation. Used for checks, controls, studies. **No. 1582**

Blowing urethane foams with fluorinated hydrocarbons discussed in new brochure. Includes advantages of making foams this way; uses of urethane foams; physical properties of blowing agent, many foamed plastics, other insulation. **No. 1583**

Latest developments in cast polyethylene film described in new booklet which deals with film casting equipment such as chill rolls and dies, and gives a comparison of properties among cast, quenched and blown films. **No. 1584**

New miniaturized infrared gas analyzer is said to be smaller than portable TV set, to weigh only 30 pounds, to accurately measure and control furnace atmospheres, dew point, combustion, toxic and combustible gases, chemicals. **No 1585**

Two new thread sealants for storable rocket propellant systems are now available, one for nitrogen tetroxide (N_2O_4) and the other for unsymmetrical dimethyl hydrazine (UDMH). Neither is impact-sensitive in these propellants. **No. 1586**

Ozone chemistry and technology covered in collection of 60 papers presented at International Ozone Conference, now being sold. Ozone now tool for organic, analytical and photo chemists, meteorologists, plant physiologists. **No. 1587**

New gas chromatography analyzer, incorporating advanced developments such as Golay columns and ionization detectors, has been introduced. Detectors permit accurate measurement of sample components in the minute quantities resolved by the Golay column. **No. 1588**

Radioactive carbon-14 compound adenosine-8-C14 now available is a radioactive purine valuable in chemistry, biology, pharmacology. Useful in study of carbohydrate metabolism since it is a constituent of plant and animal nuclei. **No. 1589**

PRODUCTS OF U.S.I.

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Ammonium Nitrate, Nitric Acid, Nitrogen Fertilizer Solutions
Sulfuric Acid: all strengths, 60 Baume to 40% Oleum. Also Electrolytic grade to Federal specifications. Tank cars or tank wagons.
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MATHESON

Compressed Gas Notes

PHOSGENE—Its use in the Laboratory

Phosgene ($COCl_2$), also known as Carbonyl Chloride and Carbon Oxychloride, is a colorless, highly toxic gas at room temperature and atmospheric pressure, having an odor resembling new mown hay. It is easily liquefied and is shipped as a liquefied gas in steel cylinders.

Phosgene is manufactured by conducting carbon monoxide and chlorine over activated charcoal at about 200°C. In World War I, it was introduced as a war gas, but it has been very actively used since its discovery by Davy in 1812 as an intermediate in organic syntheses.

Typical Uses in Organic Synthesis

1. Phosgene reacts vigorously with alcohols forming alkyl chloroformates and dialkyl carbonates, depending on the conditions of the reaction.
2. Phosgene introduced over the heated hydrochlorides of primary and secondary aliphatic amines forms alkylated carbamoyl chlorides.
3. Primary aromatic amine hydrochlorides react with Phosgene giving aryl carbamoyl chlorides, which lose hydrogen chloride on heating and form aryl isocyanates. Free aryl amines and Phosgene form N,N' —Diarylureas.
4. Secondary aromatic amines form carbamoyl chlorides with Phosgene.
5. Phosgene reacts with molten, long chain fatty acids giving good yields of acid chlorides.
6. Phosgene is used in the preparation of triphenylmethane dyes (e.g., crystal violet, ethyl violet, etc.) and in phosgenating amino azo dyes.
7. Phosgene converts phenol heated at 140-150°C. into phenyl chloroformate and diphenyl carbonate.
8. Benzene reacts with Phosgene in the presence of aluminum chloride forming benzophenone.

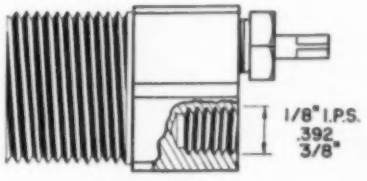
Handling Phosgene

The Matheson Company, Inc. supplies Phosgene in steel cylinders containing 150 lb., 10 lb., 5 lb. and 12 oz. (net wt.). See the Matheson Compressed Gas Catalog for prices and further information. The 150 lb. container is equipped with a valve allowing the withdrawal of either gaseous or liquid Phosgene. The smaller cylinders may be similarly equipped; however, these cylinders are usually inverted to obtain liquid Phosgene. The cylinder outlet connection and control connection for Phosgene are shown in Fig. 1.

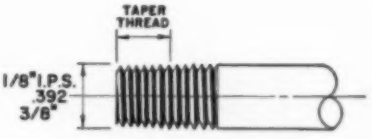
Fig. 1

CONNECTION 160

⅛" RH INT. ACCEPTING TAPERED THREADED PIPE



OUTLET



CONNECTION

The small size cylinders are ideal for laboratory use, because they are used entirely in a hood. This safety feature insures adequate ventilation for a complete system. The small cylinders will also permit rapid use of the cylinder so that unused stocks of Phosgene are not accumulated in the laboratory.

Special needle valve controls that connect directly to the cylinder valves are available to allow controlled discharge of Phosgene from the cylinder. A detailed drawing of this connection is shown in Fig. 1.

Our Sales Engineering Department will be happy to assist you in the proper handling and use of Phosgene.

Mail Coupon for Gas Catalog and Bulletins

The New Matheson Compressed Gas Catalog contains prices and data on 85 compressed gases and gas mixtures available in 5 cylinder sizes and lists a complete line of gas regulating equipment. The Cylinder Valve Outlets and Connections Bulletin contains dimensional drawings of valve outlets and connections now in common use by the compressed gas industry. Our Phosgene Bulletin gives detailed specifications and data on Phosgene Gas. All are offered without charge.

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☐ Cylinder Valve Outlet Bulletin

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equipment feature

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Granular solids mixing

Design and performance criteria for vertical and horizontal mixers and blenders.

Most free-flowing materials can be handled in either a vertical or a horizontal mixer.

In the vertical type (Figure 1), feeding is usually from the base, and the materials are raised by an elevating screw encased in a tube. At the top, the materials are flung or otherwise dispersed into the mixing tank proper where they are recirculated.

Vertical mixers range in capacity from bantam units with a capacity of 10 cu. ft. to heavy-duty mixers with capacities to 1,300 cu. ft. and higher. They are recommended for any reasonably free-flowing material, from poultry or animal feeds to industrial chemicals.

Pros and cons

Three major advantages are cited for the vertical mixer:

- Lower initial cost than a horizontal unit of the same capacity;
- Less horsepower for a given volume;
- Less floor space.

On the disadvantage side, it is generally agreed that the vertical mixer cannot produce the hourly output of the horizontal type and that, therefore, it does not offer the same mixing efficiency. Material limitations are also greater, since wet mixtures or slurries would be difficult to handle. Lastly, since complete clean-out is sometimes more difficult, contamination is less easily avoided.

How it operates

Material is fed into the bottom hopper and a horizontal feed screw transfers it at an even rate into an elevating tube. Here, the vertical screw picks it up and carries it upwards through the mixing tube. When the material reaches the top, it is distributed into the mixing chamber. One method of obtaining even distribution is a combination of slingers and baffles.

When the mixer is completely loaded, circulating mixing goes forward, with the material constantly being picked up and carried through the mixing tube and being distributed at the top. When the mixing cycle is complete, the material is discharged through one or more openings at the base of the casing cone.

Some vertical mixers are constructed as bottom loading units, with the loading hopper on the same floor as the discharge spout. In this case, all operations are conducted on one floor level.

Where the mixer is to be loaded by an air system, top loading is usually preferred and the inlet is located at the top. Such top-loading units are also required if the mixer is to be loaded from overhead bins or by screw conveyors which discharge directly into the mixer.

The most economical drive for vertical mixers consists of a motor mounted vertically on the side of the mixer with a V-belt drive to the mixer screw. Space limitations, horsepower requirements, and characteristics of the material must be taken into consideration in selecting the drive best suited to the application.

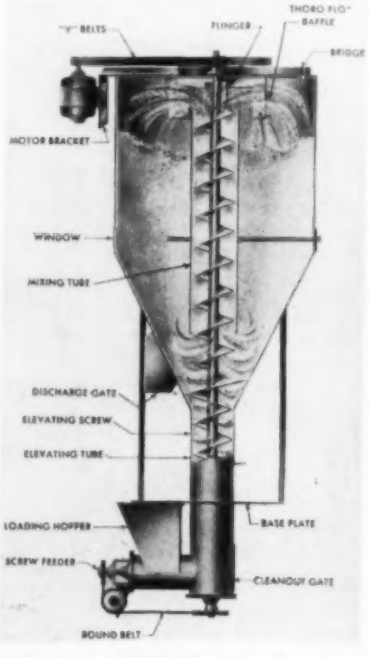

Figure 1. Schematic view of vertical mixer showing flow of materials and design features.

Twin-screw model

In addition to the single vertical screw, types are also available which have twin vertical screws mounted side by side within the same casing. Greater capacity per horsepower is claimed from the interaction of the two screws. It should be borne in mind, however, that the larger the area which is given over to the vertical screws, the smaller the total area available in the casing.

One source of difficulty in the vertical mixer is uneven dispersion of the material as it leaves the top of the mixing tube. A common construction combines the normal velocity imparted by the centrifugal action of the vertical screw itself with the action of a flinger bar attached to the screw shaft. In this design, the material is flung violently to the walls of the bin, resulting in excessive impact which may be damaging to the product and may result in stratification or segregation. Heavier particles develop greater centrifugal energy and therefore tend to travel farthest from the center of rotation. The material on its downward path toward the cervix of the cone will tend to be classified and has to depend on the intense action at the bottom of the cone itself for remixing.

Castellated baffle

This undesirable feature has been overcome in recent years by development of a castellated baffle. The open slots in the baffle permit unrestrained flight of a portion of the material as it is flung from the top of the elevating tower, but the interspaced baffles obstruct the path of some of the material, causing it to flow into an area between the outside diameter of the mixing tube and the inside diameter of the baffle ring. This action, in combination with resistance set up by material deflected from the baffles into the path of unrestricted flow, produces the desired dispersion of ingredients.

Precessional motion

Still another design of vertical mixers is one in which the vertical screw swivels at the base and rotates around

continued on page 119

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Biochemistry and Biophysics
DECEMBER 1959 VOL. 85, NO. 2 ARCHIVES OF BIOCHEMISTRY AND BIOPHYSICS
TRANSACTIONS OF THE AMERICAN SOCIETY FOR METALS Vol. 51 1959
RADIATION RESEARCH
1960
IL NUOVO CIMENTO
Vol. 11 No. 3
JOURNAL OF INORGANIC & NUCLEAR CHEMISTRY
JOURNAL OF APPLIED PHYSICS
Vol. 30, No. 5, Pages 273-432
THE JOURNAL OF PHYSICAL CHEMISTRY NOVEMBER, 1959
JOURNAL OF METALS
THE PHYSICAL REVIEW
THE REVIEW OF SCIENTIFIC INSTRUMENTS
REVIEWS OF MODERN PHYSICS
VOL. 32, No. 1, PP. 1-144
ANALYTICAL CHEMISTRY
VOL. 232, NO. 1 (PAGES 1-256)
THE JOURNAL OF BIOLOGICAL CHEMISTRY
JANUARY 1960
Properties of Reactor Materials
SECOND UNITED NATIONS INTERNATIONAL CONFERENCE ON THE PEACEFUL USES OF ATOMIC ENERGY

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Granular solids

from page 116

the interior of the vertical cone as it revolves on its axis. This precessional motion of the revolving screw flight traveling around the interior of the stationary cone body is said to offer more intimate mixing and to overcome the problems of centrifugal action at the top of the screws. In this design, the screw flights are exposed in the entire mix.

Horizontal mixers

Advantages of the horizontal design are:

- Relatively great hourly tonnage;
- Mixing efficiency is high and mixing time is short;
- Short-leg units can be mounted on the ceiling, eliminating floor obstruction;
- Hopper scale loading and surge bin discharge make them adaptable to a minimum mixing time cycle;
- A reversible ribbon mixer with two end discharges will allow for delivery of mixed products at either end. Material may be brought in at one end and taken out for bagging at the other;
- Horizontal mixers are suitable to mixes containing minor amounts of liquid, as well as for slurries;
- Drop-bottom door construction permits thorough clean-out.

Figure 2. Horizontal jacketed mixer for operation under vacuum.

Ribbon agitators are probably most widely used in solids type mixers. The most common design is one which consists of a casing of "U"-shaped section, closed at each end with a flat

continued on page 120

1952

ORIGINAL

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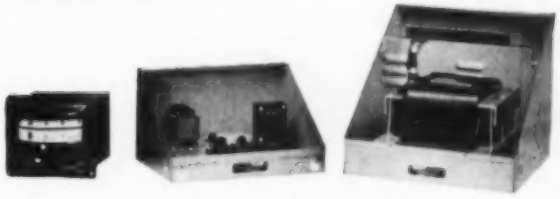

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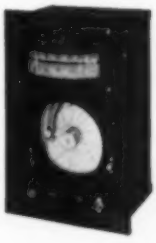

The most compact programming system available includes Model JSBG (left) for any operation involving a time-temperature cycle. Its simply cut cams integrate and control time with temperature.

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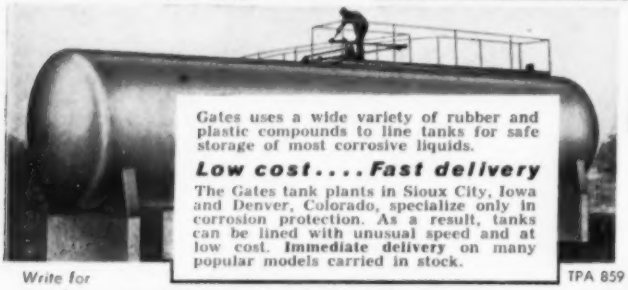
Safe storage for corrosive liquids...



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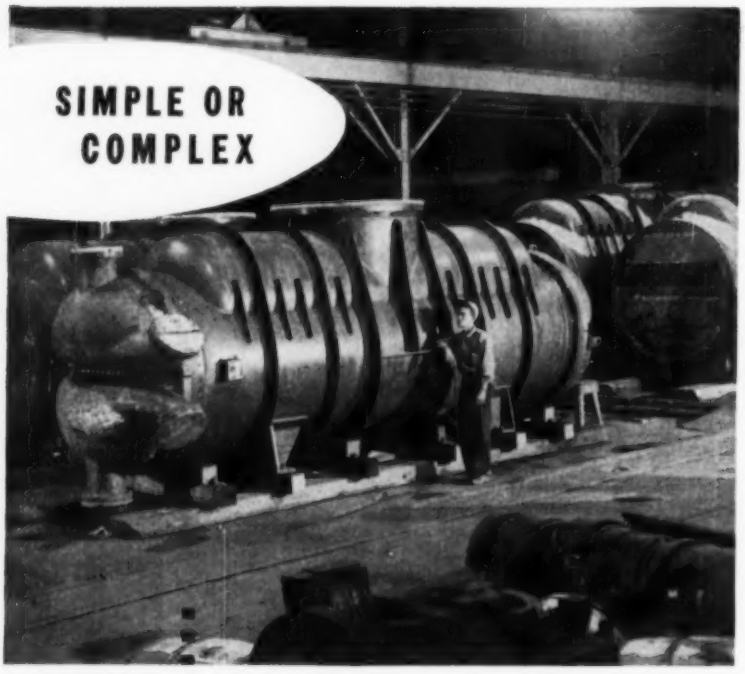

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Granular Solids

from page 119

head. The agitator may be fabricated in many styles, most of which consist basically of metal ribbons bent to form a spiral helix, or one helix inside another. The outer helix transports the materials in one direction, and the inner one reverses the flow. This, in combination with a tumbling action, results in thorough mixing. The material is conveyed, displaced outward by centrifugal force, and tumbled, rather than being steadily conveyed from one point to another as it is with the vertical screw mixer.

Ribbon mixers may be jacketed for heating or cooling, and can be either open or completely sealed. Charging is usually done through the top, either at the center or at the end, and discharging is through a bottom port which can be equipped with several different types of gates.

Ribbon blenders designed for continuous mixing may have a single spiral which agitates and transfers the material from one end of the casing to the other. In batch mixing, the opposing spirals move the materials back and forth. The inner spiral works the mix fairly slowly away from the discharge, and the outer one moves it at a slightly faster rate toward the discharge.

This type of ribbon mixer is excellent for dry powders and light pastes, provided the material does not form a cylinder around the entire agitator. For some applications, the spiral is cut out at intervals to facilitate mixing and to make it easier for the spiral to move through the mass.

Paddle mixers are somewhat similar to ribbon mixers, but they operate at slower speeds and require more power. They are available in the same wide variety of design and of materials as ribbon mixers. Both single and double shaft arrangements are available.

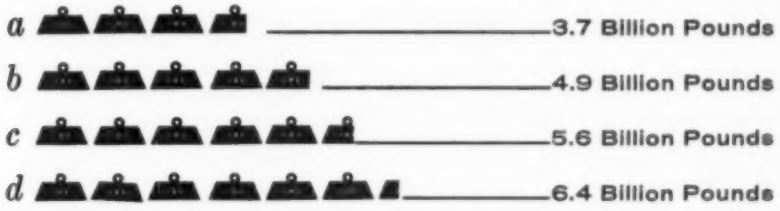
Size ranges for horizontal mixers run all the way from one cubic foot laboratory models to capacities of 2,000 cubic feet.

The most common double-ribbon agitator is designed to form a continuous, uninterrupted unit, and is of integral welded construction. Correctly proportioned ribbons are welded on substantial arms which are mounted on a heavy shaft. Combination ribbon and paddle type agitators are often recommended for mixes with liquid additives and for rapidly mixing, light, free-flowing materials. #

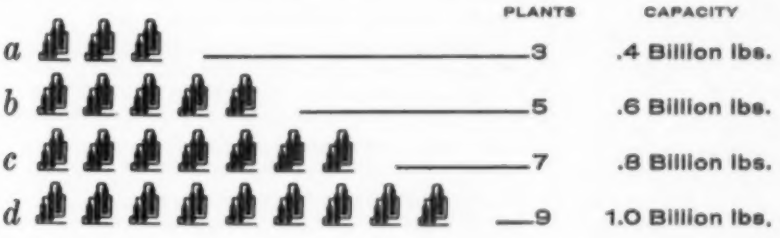
what's your best estimate?

. . . a quiz for Chemical Executives who want to keep posted

QUESTION 1. In 1959, 28 plants in the United States were producing ethylene—the hydrocarbon intermediate which is way ahead of all others both in quantity produced and in versatility. What was the estimated total U. S. capacity for this valuable chemical in 1959?



QUESTION 2. How many of the U. S. ethylene plants were designed, engineered and constructed by the Lummus Company?



ANSWERS: 1. *The answer is (c)—5.6 billion pounds, according to* Chemical Week's *Report on Ethylene, May 9, 1959.*

2. *Again the answer is (c). In the last 10 years Lummus has 7 Ethylene plants to its credit in the U. S. alone with a combined capacity of .8 billion lbs. Lummus' world-wide total is 15, with a combined capacity of over a billion pounds per year. For ethylene projects, or any type of process plant, call on Lummus' 50 years of experience in design, engineering and construction.*

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meeting preview

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Petrochemicals, chemical economics, computer techniques, cryogenic engineering will be featured at joint I.M.I.C.-A.I.Ch.E. meeting

From petrochemicals to metals, from project financing to cryogenics—almost no phase of chemical engineering will be left untouched at the coming joint Mexico City meeting of A.I.Ch.E. and the Instituto Mexicano de Ingenieros Quimicos (June 19-22).

The first of several management-slanted sessions will lead off on Monday morning—subject—Cost Estimation. Mexican and American engineers will delve into differences between U.S. and Latin American conditions and practices with particular emphasis on actual plant construction and operating costs.

Chemical Engineering in Latin America (2 sessions—Monday morning and afternoon) will highlight chemical exports, packaged petrochemical plants, planning and engineering of chemical plants in Latin America. Of particular note in the afternoon discussion will be a paper on Solar Energy Use in Latin America, which will deal with unusual solar energy applications in heating, cooling, evaporation, distillation, and drying.

Getting down to the heart of the matter—money—the final session on Wednesday morning will attack the problem of Financing International Projects.

Chemical Engineering in the Americas (Tuesday morning) will compare educational philosophies, trends, and practices in Canada, the U.S. and Mexico.

The backbone of the Mexican chemical industries, petroleum and natural gas, will be featured in another Monday morning symposium. M. Rojas Arcocha of Petroleos Mexicanos will trace the history of natural gas production in Mexico, while S. W. Curry and E. W. Schnable of UOP will peer into What is Ahead for the Refining Industry in Latin America, an extrapolation to 1969.

Two complete symposia will be devoted to Machine Computation-Optimazation, Pitfalls and Potentials (Tuesday morning and afternoon). The morning session starts with an unusual treatment of Possibilities and Difficulties for Operations Research Development in Mexico (S. Cardona Fernandez de Valle, of Patrimonio Nacional). Other papers cover optimization techniques for management decision, process development.

Full-scale symposia on Minerals and Metals, Laboratory and Pilot Plant Techniques, Cryogenic Engineering, Transfer Processes in Two-Phase Systems, Distillation Equipment, Careers in Chemical Engineering, plus three sessions of Selected Papers, round out the Mexico City Program. Complete details of all sessions are given below.

Requirements for entry into Mexico

You must carry:

1. A Mexican Tourist Card. This can be obtained upon application to the Mexican Consulate in any principal city of the United States, and also from any Mexican Government Tourist Bureau.*

2. A document proving U.S. citizenship. This can be a birth certificate, voter's certificate, passport, or the like. Naturalized citizens should take their papers with them. U.S. citizens need no passports, but resident aliens must have both passports and alien registration cards.

3. A smallpox vaccination certificate less than three years old. This is required for re-entry into the United States.

The United States Travel Agency in Washington, D.C. has arranged special flights from major areas in the United States for engineers who may want to travel together. The Agency has offered to take care of all the details of the trip, including supplying Tourist Card application forms, for members taking one of these flights from Seattle, Portland, San Francisco, Los Angeles, Chicago, Dallas, Boston, New York, Washington, Atlanta, and New Orleans. These flights will arrive in Mexico City on Saturday, June 18. Simply request United States Travel Agency, Inc., 807 15 Street N.W., Washington 5, D.C. for necessary forms and travel reservations.

For those attending the meeting who want to stay over and sightsee a bit, U.S. Travel has also set up a series of post-convention trips, all starting Thursday, June 23. Lined up are guided tours to:

Taxco and Acapulco, $138.50 per person, ends June 26.

The Gulf Tropics, (Fortin de las Flores), Panafiel, Puebla, Cuernavaca, Taxco and Acapulco, $219.75 per person, ends July 1.

Uxmal, home of the Maya Indians of Yucatan, Merida, Chichen Itza, $268.75 per person, ends June 28.

**The Mexican Government Tourist Bureaus in the United States: 8 West 51 Street, New York, N.Y.; 27 East Monroe, Chicago 27, Illinois; 735 S. Olive, Los Angeles, California; 518 West Houston, San Antonio, Texas; Columbus Hotel, Miami, Florida; 203 Charles, New Orleans, Louisiana; 901-3 Bank of America Building, San Diego, California; 142 Mellie Esperson Building, Houston, Texas. Other offices are: 26 College, Toronto, Canada; 1255 Phillips Square, Montreal, Canada; Calle 23 No. 72, Vedado, Havana, Cuba.*

One of the beauties of Mexico is the old world splendor of its great churches.

Three-Day Schedule of Technical Sessions

MONDAY, JUNE 20

9:00 A.M.-12 Noon

TECHNICAL SESSION NO. 1—PETROLEUM AND NATURAL GAS PROCESSING IN LATIN AMERICA—Part I.
Chairman: F. W. Jessen, Univ. of Texas.
Co-chairman: F. L. Corcuera, Refineria Madero.

Natural Gas and Natural Gas Industries in Mexico, M. Rojas Arcocha, Petroleos Mexicanos. History of natural gas production in Mexico.

What is Ahead for the Refining Industry in Latin America?, S. W. Curry & E. W. Schnabel, Universal Oil Products. Growth of the refining industry extrapolated to 1969.

Natural Gas Processing Developments, C. E. Webber & J. Walke, Sun Oil. Commercial and technical aspects of the natural gas liquids industry.

Lubricating Oils in Mexico, W. B. Bassett, Lubrizol Corp. Progress in base stock developments in Mexico.

TECHNICAL SESSION NO. 2—COST ESTIMATION.
Chairman: R. Voorhees, Union Carbide Development.
Co-chairman: R. Pardo, Bufete Industrial.

Difference Between United States and Latin American Chemical Industry, C. E. Waring, W. R. Grace. Basic differences between U. S. and Latin American conditions in regard to construction and operating costs.

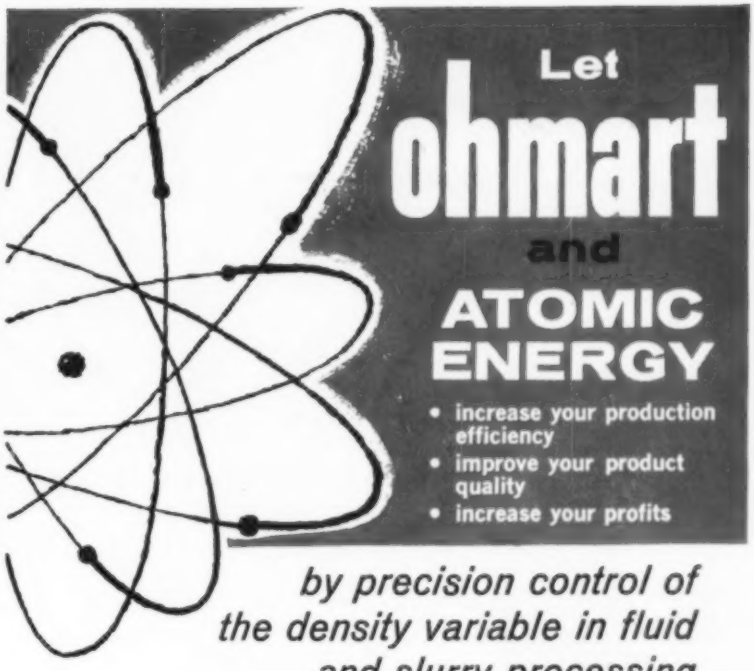
Actual Construction and Operating Costs from the Latin American Point of View, R. Pardo, M. Girault, Jr., E. Davalos O., & C. Aedo, Bufete Industrial. Case history data on construction and installation costs of chemical plants in Mexico.

Estimation of Construction Costs in Latin America from the U. S. Point of View, G. R. Lawrence, Lummus. Principal elements of plant investment and their usual relative proportions.

Estimation of Manufacturing Costs in Latin America from the U. S. Point of View, J. F. Flanagan, Monsanto Chemical. Comparative estimates of labor and other elements of manufacturing costs in Mexico, Argentina, and the U. S.

Construction and Operating Costs in Latin America Compared with Other Parts of the World, G. F. Jenkins, Union Carbide International. Latin American costs compared with Europe, India, and Australia.

continued on page 124



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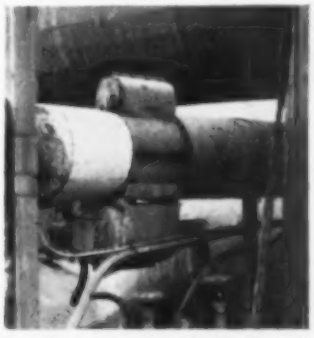

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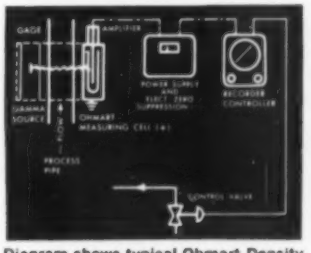

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Technical session

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TECHNICAL SESSION NO. 3—MINERALS AND METALS.
Chairman: D. B. Coghlan, Foote Mineral.
Co-chairman: V. Carreto de la Mora, Equipos de Proceso.

Cadmium Plant at the Lead Smelter of Cia. Metallurgica Penolas, F. W. Gibson, Cia. Metallurgica Penolas. An improved process for production of 99.9% cadmium as a lead smelter by-product.

Production and Melting of HYL Sponge Iron, J. Celada, Fierro Esponja. Development of the HYL process and technical aspects of production plants.

Soaring Sulphur, G. Giusti, Texas Gulf Sulphur. Review of the sulfur industry showing world-wide production and consumption.

Fluidized-Bed Process for Production of Niobium, J. H. Oxley, Battelle Inst., G. H. Kesler & I. E. Campbell, National Steel. Niobium metal in a fluidized-bed reactor by hydrogen reduction of niobium pentachloride.

The Use of Underground Nuclear Explosions for Mining Sulphur, J. M. Dale & R. C. DeHart, Southwest Research Inst. Evaluation in the light of the latest nuclear technology.

TECHNICAL SESSION NO. 4—CHEMICAL ENGINEERING IN LATIN AMERICA—PART I.
Chairman: G. Mayurnik, W. R. Grace.
Co-chairman: G. Ahumada, Celanese Mexicana.

The Export Aspects of the Chemical Industry, W. Wickersham, Allied Chemical. Aspects of the chemical export business with particular reference to its mechanics, problems, and peculiarities.

Packaged Plants for Latin American Petrochemical Industry, R. Landau, Scientific Design. A basic method of initiating a successful and competitive petro-chemical industry in Latin America.

Case Study of Chemical Development, O. Phillips M., Instituto de Investigaciones Tecnologicas. The technical, social, and economic conditions affecting design and operation of a chemical industry in Colombia.

Staffing the Oversas Plant, R. N. Augustson, Monsanto Chemical. Basic policy behind Monsanto's practices in staffing its overseas operations.

3:30 P.M.-6:30 P.M.

TECHNICAL SESSION NO. 5—PETROLEUM AND NATURAL GAS PROCESSING IN LATIN AMERICA—PART 2.
Chairman: F. W. Jessen, Univ. of Texas.
Co-chairman: F. L. Corcuera, Refineria Madero.

An Approach on Petrochemicals and their Importance in the Mexican Frame, F. Lara Sosa, Petroleos Mexicanos. Fundamental aspects of Mexican crudes, details of cracking and reforming units.

The Odorization of Liquefied Petroleum Gases, J. Baraquiel Calva, J. B. Calva Co. Safety, technological and economic problems, thermodynamic aspects.

Dehydration of Poza Rica Crude with Chemical Demulsification, E. Cervera del Castillo, Petroleos Mexicanos, & R. E. Power, Petrolite Corp. Field testing of emulsions and plant design.

TECHNICAL SESSION NO. 6—LABORATORY AND PILOT PLANT TECHNIQUES.
Chairman: J. T. Cumming, Penn College.
Co-chairman: M. Puebla, Instituto Mexicano de Investigaciones Tecnologicas.

An Electrolytic Zinc Pilot Plant, R. E. Lund, St. Joseph Lead. Recovery of electrolytic zinc from solutions resulting from selectively sulfating a refractory pyritic ore.

Pilot Plant Operations in the Fine Chemical Industry, J. Gillin & P. G. Colin, Merck. Three unit processes discussed with emphasis on piloting problems.

Hydrogenation Techniques at Combined High Temperatures and Pressures, E. B. Shultz, Jr., H. L. Feldkirchner, & E. J. Pyrchioch, Institute of Gas Technology. Novel high-pressure pilot plant equipment for processing solid and liquid fossil fuels by destructive hydrogenation.

Filtration for Clarification, N. J. Foecking & F. C. Goldsmith, Lubrizol Corp. Method for selection of admixed filter aid giving clarity with the optimum filtration cycle.

An Automatic Pilot Plant for Fixed-Bed Catalytic Processes, S. E. Shields & A. B. Groh, Standard Oil (Indiana). Features and performance of a versatile pilot plant.

TECHNICAL SESSION NO. 7—CRYOGENIC ENGINEERING.
Chairman: F. Kurata, Univ. of Kansas.
Co-chairman: B. Pacheco, Liquid Carbonic de Mexico.

Basic Aspects of Cryogenic Engineering, J. G. Daunt, Ohio State Univ. Production of low temperatures, liquefaction of gases, separation and purification of gases and isotopes at low temperatures.

Liquid Hydrogen—The Ultimate Fuel, P. C. Vander Arend & B. J. Ferro, Air Products. Details of the process for large-scale liquid hydrogen production.

The Adsorption of Impurities from Hydrogen Gas at Low Temperatures, M. J. Hiza, National Bureau of Standards. Design data for large-scale purification of hydrogen gas.

Heterogeneous Phase and Volumetric Behavior of the "Methane-n-Heptane System of Low Temperatures, J. P. Kohn, Notre Dame. Vapor-liquid, solid-liquid, solid-vapor, solid-liquid-vapor, and liquid-liquid-vapor equilibria down to minus 200°F.

Volumetric Properties of Gas Mixtures at Low Temperatures and High Pressure by the Burnett Method: The Hydrogen-Methane System, W. H. Mueller, T. W. Leland, & R. Kobayashi, Rice Inst. Experimental data used to obtain the second virial coefficients for pure methane and for the mixtures.

Application of the Corresponding States Principle to Mixtures of light Gases at Low Temperatures, W. H. Mueller, R. Kobayashi, & T. W. Leland, Rice Inst. Principle of corresponding states for mixtures extended to mixtures of low molecular weight gases at low temperatures.

TECHNICAL SESSION NO. 8—CHEMICAL ENGINEERING IN LATIN AMERICA—PART 2.
Chairman: G. Mayurnik, W. R. Grace.
Co-chairman: G. Ahumada, Celanese Mexicana.

Planning and Developing a Process Industry in Mexico, J. Mendoza Fernandez, Bufete Industrial. Technical and economic problems related to development of a new process industry in Mexico.

Problems in Engineering of Chemical Plants in Latin America, S. Strelsoff, Chemical Construction Corp. Negotiation of the contract, financing of the project, execution of the contract.

Solar Energy Use in Latin America, G. O. G. Lof & J. A. Duffie, Univ. of Wis. Examples of solar energy applications in heating, cooling, evaporation, distillation, and drying.

TUESDAY, JUNE 21

9:30 A.M.-12:30 P.M.

TECHNICAL SESSION NO. 9—CHEMICAL ENGINEERING EDUCATION IN THE AMERICAS—PART 1.
Chairman: W. R. Marshall, Jr., Univ. of Wis.
Co-chairman: F. Garcia Roel, Instituto Tecnologico y de Estudios Superiores de Monterrey.

Chemical Engineering Education in Mexico, J. Noe Martinez, Monsanto Mexicana. The present system and curriculum used by the different schools in Mexico and the trend and philosophy followed.

Chemical Engineering Education in Canada, G. W. Govier, Univ. of Alberta. Typical Canadian undergraduate and graduate requirements, staff, space, and equipment.

Fifty Years of Chemical Engineering Education in the United States, O. A. Hougen, Univ. of Wis. Critical appraisal of gains and losses in capabilities and responsibilities of the young chemical engineer.

PART 2—PANEL DISCUSSION.
Moderator: F. Garcia Roel, Instituto Tecnologico y de Estudios Superiores de Monterrey.

TECHNICAL SESSION NO. 10—MACHINE COMPUTATION-OPTIMIZATION, PITFALLS, POTENTIAL—PART 1.
Chairman: W. M. Carlson, Du Pont.
Co-chairman: B. Bucay, Monsanto Mexicana.

Possibilities and Difficulties for Operations Research Development in Mexico, S. Cardona Fernandez de Valle, Secretaria Patrimonio Nacional. Average size of enterprises, peculiar cost distributions, psychology of top executives will force O. R. development into a pattern different from that of other countries.

Role of Optimization Techniques in Management Decision, R. B. Grant, Phillips Petroleum. Role of simulation in plant operation studies and in broader economic analyses.

Optimization in Process Development, C. Berg, Union Oil of Calif. Optimization is the key to the successful culmination of any development venture.

continued on page 126

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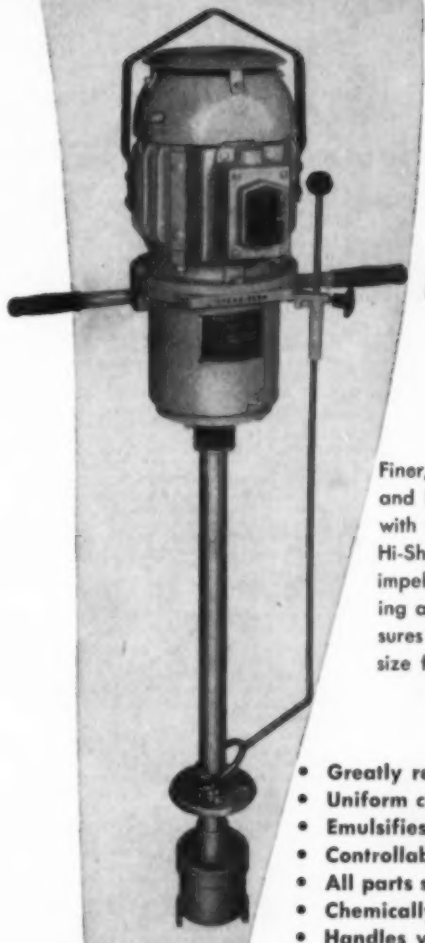

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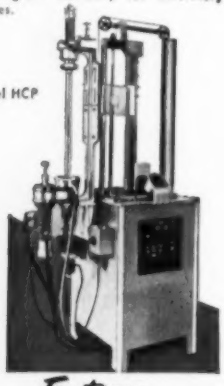

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Technical session

from page 125

Optimization in Machine Design, J. T. Lester, Jr., Du Pont. Efficient analysis methods described and compared.

Optimum Inventory Policies of Sub-Groups in Manufacturing and Distribution, K. J. Rose, Minnesota Mining and Manufacturing. An over-all system broken down into smaller groups, and individual optimum policies and decision rules determined for each of the sub-groups.

TECHNICAL SESSION NO. 11—TRANSFER PROCESSES IN TWO-PHASE SYSTEMS—PART 1.

Chairman: S. G. Bankoff, Northwestern Univ. Co-chairman: A Hoyos Macedo, DIN, S.A.

The Multiphase Hypersonic Laminar Boundary Layer on a Flat Plate. Part 1: Boundary Layer Solutions. Part 2: A Simplified Calculation Method, J. P. Hartnett & C. Y. Koh, Univ. of Minnesota. A simplified numerical method applicable to glass and other melting-vaporizing materials.

Transient Ablation and Heat Conduction Phenomena at a Vaporizing Surface, R. G. Fledderman & H. Hurwicz, Avco RAD. Transient heat and mass transfer in a vaporizing solid (or liquid) subject to external heat flux investigated at the solid (liquid)-vapor interface and inside the solid.

Gas Dynamic Processes Involving Suspended Solids, S. L. Soo, Univ. of Ill. Basic gas dynamic equations involving suspended solid particles.

A Model for Correlating Two-Phase, Steam-Water Burnout Heat Transfer Fluxes, H. S. Isbin, H Fauske, S Singh, & R. Vanderwater, Univ. of Minn. A model applied to data at 2,000 lb./sq. in. abs. for upward flow in rectangular and round channels, with uniform and hotpatch heating.

Further Studies of Fluid Flow and Mass Transfer in Trickle-Bed Reactors, W. N. Schiesser & L. Lapidus, Princeton Univ. Residence-time behavior of a liquid flowing through a trickle-bed reactor investigated by tracer techniques.

TECHNICAL SESSION NO. 12—SELECTED PAPERS—PART 1.

Chairman: J. A. Samaniego, Shell Development. Co-chairman: S. L. Sampson, Mexico City.

Heat Transfer to Pseudoplastic Fluids in Laminar Flow, E. B. Christiansen, Univ. of Utah, & S. E. Craig, Phillips Petroleum. Equations for accurate prediction of heat transfer coefficients in heating of pseudoplastic and Newtonian fluids.

Heat Transfer to Liquids with Gas Injection Through the Boundry Layer, E. E. Gose, A. Acrivos, & E. E. Peterson, Univ. of Calif. Heat transfer between non-boiling liquids and porous solids with a gas flowing through the pores.

Thermal Conductivities of Unconsolidated Particles with Flowing Fluids, D. Kunii & J. M. Smith, Northwestern Univ. Heat transfer between unconsolidated solid particles in a packed bed and several flowing fluids.

Hydraulic Analog Computing Machine for the Solution of Heat Transfer Problems, C. Duhne, Instituto Tecnologico y de Estudios Superiores de Monterrey. Description and uses of a high-precision hydraulic analog computer.

A Contribution to the Calculation of Regenerators Using Charts Obtained by a Hydraulic Analog Computer, C. Duhne & H. Cano Garcia, Instituto Tecnologico y de Estudios Superiores de Monterrey. Use of hydraulic analog computer data in design of regenerative furnaces.

TECHNICAL SESSION NO. 13—STUDENT PROGRAM—CAREERS IN CHEMICAL ENGINEERING. Chairman: J. J. McKetta, Univ of Texas. Co-chairman: J. N. Martinez, Dow Chemical Inter-American.
Panelists to be announced:

RESEARCH AND GRADUATE STUDIES, J. J. McKetta, Univ. of Texas.

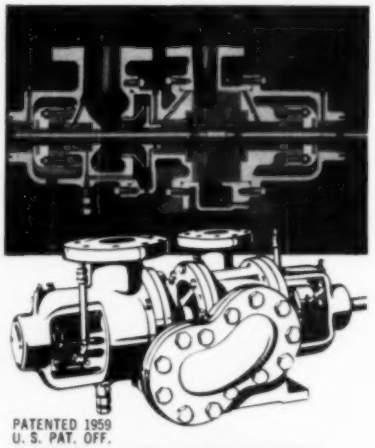
DESIGN AND DEVELOPMENT, J. Happel, New York Univ.

PLANT OPERATIONS, H. D. Guthrie, Shell Oil.

4:00 P.M.-7:00 P.M.

TECHNICAL SESSION NO. 14—MACHINE COMPUTATION - OPTIMIZATION, PITFALLS, POTENTIALS—PART 2.

Chairman: W. M. Carlson, Du Pont.
Co-chairman: B. Bucay, Monsanto Mexicana.



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Mathematical Optimization and Operations Analysis—A Brief Survey, P. Uribe Castaneda, Investigacion de Operaciones, S.A. Review of classical O.R. problems that might be stated as extreme-value probelms.

Design of Process Equipment to Economic Optimum, J. J. Taborek, Phillips Petroleum. Equipment design to economic optimum by three different methods, relative merits discussed.

Reaction Kinetics Optimization Using Non-Linear Estimation, T. I. Peterson, IBM. Non-linear estimation program for digital computer augmented to permit systematic generation of kinetic models and evaluation of plausibility.

Dynamic Programming Formulation of the Catalyst Replacement Problem, S. M. Roberts, Thompson-Ramo-Wooldridge Products. Theory outlined and computational procedure described.

A Control Technology for Chemical Engineering Systems, S. Shapiro, E. Shapiro, & R. E. Stillman, IBM Research Labs, L. Lapidus, Princeton Univ. A non-linear system with three control variables subjected to various gradient techniques.

TECHNICAL SESSION NO. 15—TRANSFER PROCESSES IN TWO-PHASE SYSTEMS—PART 2.
Chairman: S. G. Bankoff, Northwestern Univ. Co-chairman: A. Hoyos Macedo, DIN, S.A.

Macroscopic Mixing in Fluidization, E. J. Cairns, GE Research Labs. & J. M. Prausnitz, Univ. of Calif. Mixing studies in beds of lead and glass particles fluidized with water.

Effects of Acceleration on Nucleate Pool Boiling, C. P. Costello & W. E. Tuthill, Univ. of Wash. The effects of high local gravity fields on pool boiling heat transfer to water.

Mass Transfer Between Isobutanol and Water in Co-current Flow Through a Packed Column, J. A. Leacock & S. W. Churchill, Univ. of Mich. Local rates of transfer of isobutanol into the water-rich phase, and of water into the isobutanol-rich phase measured in co-current flow through a column packed with glass spheres.

Solution and Evolution of Gases and Vapors in Aircraft Fuels, M. Markels, Jr., Atlantic Research. Agitation in series of tanks when shaken laterally at various amplitudes and frequencies.

Response of a Liquid-Gas Interface to Concentration Pulses, R. L. Pigford & S. Whitaker, Univ. of Del. Response of a 0.004 inch thick liquid film to a sinusoidally varying sulfur dioxide pressure for frequencies ranging from one to ten cycles per second.

TECHNICAL SESSION NO. 16—SELECTED PAPERS—PART 2.
Chairman: J. A. Samaniego, Shell Development. Co-chairman: S. L. Sampson, Mexico City.

Phase Equilibria of the Propane-Hydrogen Sulfide System from the Cricondontherm to the Solid-Liquid-Vapor Region, J. Brewer, N. Rodewald, & F. Kurata, Univ. of Kansas. Phase equilibria data for propane-hydrogen sulfide below 32°F to the solid-liquid-vapor region.

Liquid-Vapor Equilibria in the Hydrogen-Nitrogen Deuterium-Nitrogen Systems, A. Maimoni, Univ. of Calif. Vapor-liquid equilibrium data for hydrogen-nitrogen and deuterium nitrogen at 90 and 95°K up to 1,000 lb./sq. in. abs.

The Distribution of Nitric Acid Between Water and Tributyl Phosphate-Hexane Solvents, D. R. Orlander, Univ. of Calif., L. Donadieu & M. Benedict, MIT. Distribution of nitric acid between water and tributyl phosphate-hexane solutions beyond the range of acid and TBP concentrations previously reported.

An Experimental Method for the Estimation of Minimum Reflux Ratios in Distillation Columns, K. Green, Phillips Petroleum. & J. O. Maloney, Univ. of Kansas. An experimental technique to determine minimum reflux ratios.

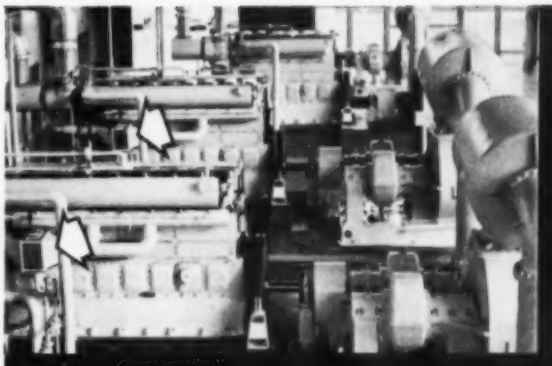
Development and Operation of a New Type of Solid-Liquid Extractor, H. Lopez Ramos, Instituto Tecnologico y de Estudios Superiores de Monterrey. Description of a new continuous solids-liquid extractor.

WEDNESDAY, JUNE 22

9:00 A.M.-12 Noon

TECHNICAL SESSION NO. 17—SELECTED PAPERS—PART 3.
Chairman: J. A. Samaniego, Shell Development. Co-chairman: S. L. Sampson, Mexico City.

continued on page 128



Three of the five multi-fuel engines at a midwest sewage plant cooled by Young Intercoolers.

Young-engineered Intercooler, one of three furnished as cooling components for turbocharged engines.

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SUPERCHARGER AIR INTERCOOLERS BY YOUNG

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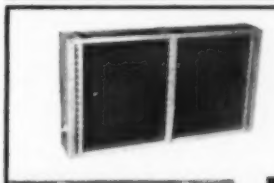

2-Cycle Scavenging Air Coolers

Burning sludge gas in the multi-fuel engines of this modern sewage treatment plant, saves about $50,000 yearly. Further savings are made by using turbocharged engines using Young efficient intercoolers. Actual horsepower of 4 cycle Diesel, natural gas and dual fuel engines has been increased by approximately 50% over a normally aspirated engine through the use of supercharger blowers. Tests and field installations show that intercooling of supercharged air before admission to the cylinders increases the horsepower of the engine from 10% to 33% over supercharged, non-intercooled engines. Over three decades of Young engineered engine cooling experience is at your service to help you solve your cooling problems.

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Young intercooler cores are available in several varieties of plate fin core specifications for high or low pressures. Plate fins are made of copper, aluminum, or Admiralty metal to meet service requirements. For marine applications Young Supercharger Intercoolers may have cast or fabricated housing, cast bronze header tanks, salt water resistant tubes and tube header sheets. Where further resistance to salt water action is required, they are equipped with zinc pencil inserts.

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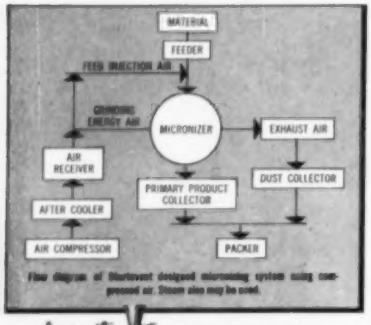

Flow diagram of Sturtevant designed micronizing system using compressed air. Steam also may be used.

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Sturtevant Micronizers grind and classify in one operation in a single chamber—provide fines in range from ½ to 44 microns to meet today's increased product fineness needs. Can handle heat-sensitive materials.

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Particles in high speed rotation, propelled by compressed air entering shallow chamber at angles to periphery, grind each other by violent impact. Design gives instant accessibility, easy cleaning. No moving parts.

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Centrifugal force keeps oversize material in grinding zone, cyclone action in central section of chamber classifies and collects fines for bagging. Rate of feed and pressure control particle size.

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Grinding chambers range from 2 in. diameter laboratory size (½ to 1 lb. per hr. capacity) to large 36 in. diameter production size (500 to 4000 lbs. per hr. capacity). For full description, request Bulletin No. 091.

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A 30 in. Sturtevant Micronizer is reducing titanium dioxide to under 1 micron at feed rate of 2250 lbs. per hr. For another firm, a 24 in. model grinds 50% DDT to 3.5 average microns at a solid feed rate of 1200-1400 lbs. per hr. A pharmaceutical house uses an 8 in. model to produce procaine-penicillin fines in the 5 to 20 micron range. Iron oxide pigment is being reduced by a 30 in. Micronizer to 2 to 3 average microns.

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For more information, circle No. 28

Technical session

from page 127

Relation Between Pellet Size and Performance of Catalysts, J. Beck, Shell Development. Simultaneous effects of resistance to mass and heat transfer on the effectiveness of porous catalysts.

Efficiency of Continuous Rotary Drum Filtration, H. R. Cooper, Fluor Corp. Filter media resistance in continuous rotary drum filtration correlated for estimation of plant performance.

Design and Operating Experience of HCl Absorber and Stripper, L. B. Reynolds & J. B. Bingeman, Ethyl Corp. Design and operating data for a unique HCl aqueous absorption-stripping plant.

The Chemical Market and Industry in Mexico, E. Rangel Trevino, Dow Chemical Inter-American. Development of the Mexican chemical market and industry.

Investment Estimating Methods of Chemical Plants in Mexico, P. Larraza, Sintesis Organicas, S.A. Recommended methods for estimation of purchase and installation of process equipment.

TECHNICAL SESSION NO. 18—DISTILLATION EQUIPMENT.
Chairman: R. Katzen, R. Katzen Associates.
Co-chairman: F. Ocampo Torrea, Petroleos Mexicanos.

Free Entrainment Behavior in Sieve Trays, S. I. Cheng & A. J. Teller, Univ. of Florida. An analysis based on the effects of projection velocity, size distribution, drag, and system properties.

Entrainment from Perforated Trays at Low Tray Spacings, L. Friend, E. J. Lemieux, and W. C. Schreiner, M. W. Kellogg Co. Data on liquid entrainment for perforated bubble trays on 6-, 9-, and 12-in. spacings for an air-water system.

Efficiency Tests in a Bubble-Plate Column, J. A. Celestinos Isaacs, Petroleos Mexicanos. Results compared with existing design formulas

Separating Aromatics from Petroleum Mixtures of Paraffins, Napthenes, and Aromatics, E. L. Ekholm, Pace Co. Using the concept of internal pressure, limited binary data can be extended to complex systems without elaborate laboratory studies.

Plate Efficiency in Distillation of Oxygen-Nitrogen-Argon Mixtures, A. Matesanz, General Dynamics. Experimental equipment for determining plate efficiency and direct visual observation of distillation conditions of cryogenic mixtures.

TECHNICAL SESSION NO. 19—FINANCING INTERNATIONAL PROJECTS.
Chairman: P. F. Genachte, Chase Manhattan Bank.
Co-chairman: J. L. Oria, Credito Bursatil, S.A.

FRIA—The Development of African Mineral Resources, W. P. O'Connell, Olin Mathieson. History of project, facilities, financing plan, legal complications, government participation.

Inadequate Profits—The Prime Problem of the Chemical Industry, C. A. Gerstacker, Dow Chemical. Rising costs and fierce competition, which has prevented compensating price increases, have resulted in profit margins which are inadequate to properly finance research and development.

The Financing Aspects of the Chemical Industry versus the Earnings Picture, E. B. Morrow, Hercules Powder. Earnings should be sufficient to pay reasonable cash dividends on operating assets and to provide retained earnings which will finance the growth of the business.

Future of Industrial Financing in Mexico, G. Romero Kolbeck, Direccion de Inversiones Publicas. Financing sources in Mexico and present problems of industrial financing.

Industrial Financing and Promotion by Private Banks in Mexico, M. de la Peza, Banco Nacional de Mexico. Industrial growth in Mexico and present Mexican industrial and market conditions.

An industrial adhesive plant just built by Armour Alliance Industries is equipped to make resin-base and other type adhesives. Third in a series of industrial adhesive plants built by Armour within the past year, it will service customers throughout the Eastern United States.

. . . one of a series presented by Western Supply Company, Tulsa, to improve the "I.Q."* of engineers . . .
(*"Income Quotient")

Personal, professional advancement demands thorough engineering knowledge, disciplined habits, creative thinking, constant application

"Intellectual let-down" — that tendency so common to many engineers to "stop learning" as soon as they acquire a sheepskin — will be completely out of style by 1999. Indeed, it is passe in today's accelerated engineering profession, because to stop learning is to stop growing: to stifle imagination, to throttle creativity, and ultimately to kill scientific progress.

The engineer who would keep pace with his own industry — especially the process industry — must determine to follow a prescribed, disciplined cou..e of action, if he is to achieve the stature, prestige, responsibility and income to which he aspires. He must recognize that only as his engineering achievement advances will his personal well-being also increase.

There is no magic formula for the "successful engineer," but for what they are worth to your professional future, here are 14 "ground rules" for your consideration:

Set objectives for your professional and personal life, re-examine them periodically, but always work towards a goal in life.

Develop sound work habits. Earn a reputation for promptness, attention to detail, accuracy, diligence, reliability.

Continue to study your chosen field or specialty. Your learning process must never cease functioning.

Seek additional training, technically or in non-technical fields which can be of importance to future development.

Think creatively about your job, your company, technological advances and developments. Dare to think **beyond** your capacity.

Expand your capacity to discover new fields of endeavor, discriminatingly, however, so that they will have application to your objectives.

Take a genuine interest in people, their potentials, their problems. Understand, but don't condemn, their shortcomings.

Broaden your base of appreciation for other pursuits, such as sales, accounting, law, advertising. They, too, are important to your company.

Study the fundamentals of business. Learn the economics of your company, its basic philosophy, its obligations and responsibilities, its opportunities and limitations.

Seek advice and counsel from others; don't rely entirely on your own resources . . . Ask questions.

Participate actively in technical societies; keep alert to professional trends, changing concepts, new developments.

Use **common sense** and sound, practical judgment in evaluating everything from people to processes.

Aggressively pursue your professional and personal ambitions, but with patience and intelligence.

Learn to communicate your ideas and opinions pleasantly, clearly, concisely, aggressively to your superiors, associates, subordinates.

The development of a successful career in engineering bespeaks **constant, consistent dedication** to professional and personal principles. Perhaps these few paragraphs can serve as a guide for your own engineering future and advancement. (Footnote: for more detailed discussion of the suggestions made herein, write for your free copy of "14 Ground Rules," to WESTERN SUPPLY COMPANY, HEAT EXCHANGER DIVISION, P. O. BOX 1888, TULSA, OKLA. — and if there's a heat exchanger in your company's future, we'd like to demonstrate how these "14 ground rules" affect our heat exchangers!

For more information, circle No. 19

industrial news

One of the first self-contained polycarbonate resin manufacturing plants in the country, is GE's new installation near Mount Vernon, Indiana. Expected to be in operation by the end of the year, the multi-million pound per year unit is a further scale-up of semi-works and pilot plants that have produced more than 200 applications of GE's Lexan polycarbonate resin.

A new citric acid production enterprise calls for construction of a $1½ million plant near Mexico City. The Miles process will be used. (This calls for cane sugar, a surplus commodity in Mexico). The all Mexican operation is headed by Quimica Mexama, S. A., a company formed by a group of Mexican investors in partnership with Miles Laboratories.

More expansion at Dow Chemical, this time with a $30 million program at the Louisiana Division, Plaquemine, La. Construction includes an ammonia plant, increase in capacity for chlorine, caustic soda, and vinyl chloride units. The ammonia plant will make both anhydrous and aqueous ammonia.

The chemical industry of the East German Republic will have an ethylene plant, 40,000 tons annual capacity, built by a leading British firm. The order for design and engineering of the first part of the project was signed recently in London. Representatives of the East German Foreign Trade Enterprise, "Dia-Chemieausrustungen", Humphreys & Glasgow, and Petrocarbon Developments, were involved. This is believed to be the first time that British companies have obtained a contract for a complete chemical plant for Eastern Germany. It is one of the first results of an amendment to the 1959 trade agreement between the Federation of British Industries and the Chamber of Foreign Trade, German Democratic Republic.

An acetylene plant which uses the methane cracking method has been put into service in France by Houillères du Bassin de Lorraine. The new unit at Carling (Moselle) France, said to be one of the first plants using the Belgium Azote technique, uses methane which comes from coke oven gas from the company's Carling and Marienau plants. It is part of the company's program to increase coke delivery to iron and steel industry in Lorraine.

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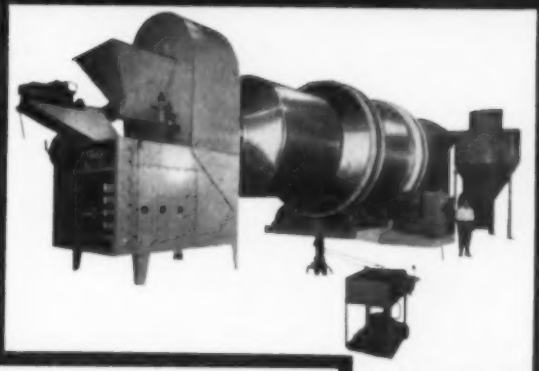
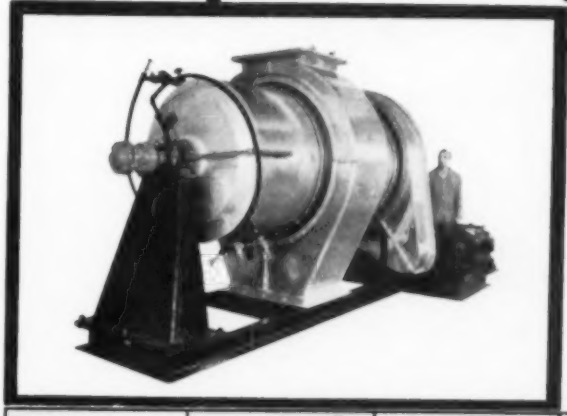
Renneburg low temperature, variable inclination, rubber-tired, steam-heated DehydrO-Mat Dryer for ammonium nitrates and other hard-to-dry chemicals requiring long hold-up times.





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industrial news

A phthalic anhydride plant, to be constructed at Schoonarde, Belgium, has a design capacity of 5000 metric tons a year. Design contract for $2 million unit went to Badger, N. V., from Union Chimique Belge, S. A.

An expansion in synthetic phenol capacity at Allied Chemical, Plastics and Coal Chemicals Division, is due for completion late this year, at the Philadelphia, Pa. plant.

Plans for construction in England of melamine resin plant are under way at American Cyanamid. The new facility, located on land adjacent to the company's pharmaceutical plant at Gosport, due for start-up early next year. It is expected to give British manufacturers of molding compounds, laminating resins and other derivatives a new source of supply.

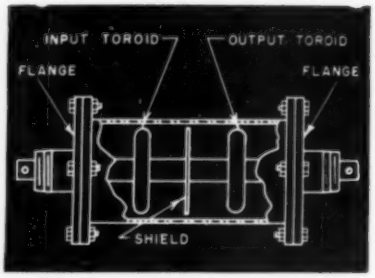
A detergent and detergent chemicals plant is under construction at Ultra Chemical Works (Witco Chemical). Plans call for a 30 million pound annual capacity of dodecyl benzene sulfonate; location is Witco's site in the clearing area of Chicago.

A plant to make methylamines is being added by Du Pont to its Belle, West Virginia, site. Completion of the new unit is expected to more than double company capacity for methylamine, now produced at the Houston, Texas, works. In additon to dimethylamine, the plant will make methylamine derivatives dimethyl-formamide, and dimethylacetamide.

News on the international styrene front: another styrene plant goes on stream in Australia. C.S.R.C. Dow Pty, facilities are due to be completed in July 1961. Location is in Altona.

Also on the international scene: In Greece, a subsidiary company to manufacture styrene plastic is being formed by Dow Chemical. The Greek government has approved a million dollar investment by Dow in a polystyrene plant, believed to be the first in the country. Imported raw materials will be used in production. Output is scheduled for both the Greek market and for export. Site of the company which will be held by Dow Chemie of Switzerland, has not yet been selected.

Increased demand for aluminum fluoride has resulted in Stauffer Chemical plans to expand plant capacity at its Nyotex Division, Houston, Texas. This will double company production based on a fluidized bed process.



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A.I.Ch.E Candidates

The following is a list of candidates for the designated grades of membership in A.I.Ch.E. recommended for election by the Committee on Admissions. These names are listed in accordance with Article III, Section 8 of the Constitution of A.I.Ch.E.

Objections to the election of any of these candidates from Members and Associate Members will receive careful consideration if received before May 15, 1960, at the office of the Secretary, A.I.Ch.E., 25 West 45th Street, New York 36, N. Y.

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Casteel, David E., *Detroit, Mich.*
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Cooper, William M., *Raleigh, N. C.*
Costero, Jose Luis, *Mexico D. F., Mexico*
Dalzell, William, *Plainfield, N. J.*
Davis, James Edward, *Detroit, Mich.*
de Cardenas, Antonio, *Vedado Habana, Cuba*
Dickens, Charles A., *Beacon, N. Y.*
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Fudge, Thomas G., *Kingsport, Tenn.*
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Giovanetti, Albert, *Moundsville, W. Va.*
Gonzalez, Jesus Rene, *Nuevo Laredo, Mexico*
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Graves, George H., *Rolla, Mo.*
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Hallow, William C., *Camden, N. J.*
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continued on page 135

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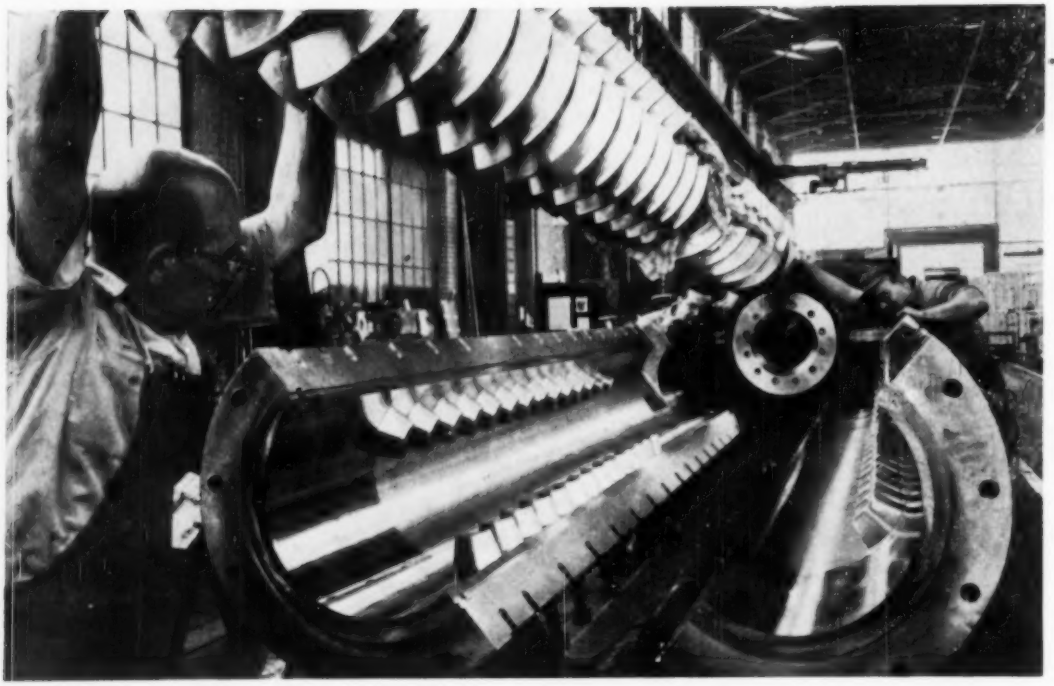
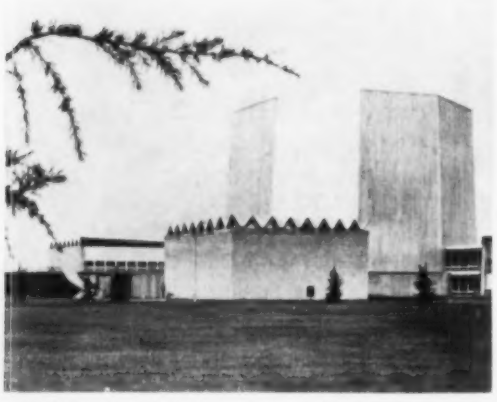
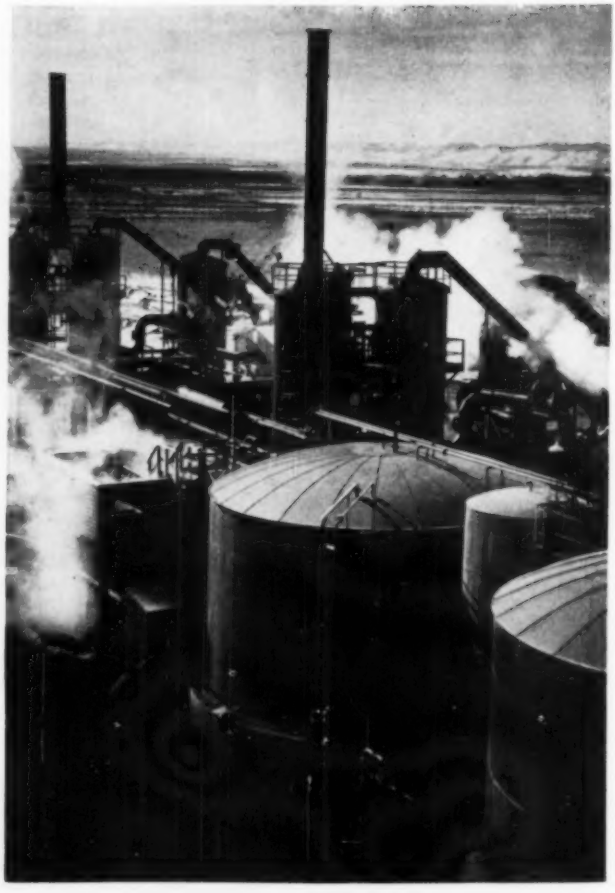


THIS 40-FT., 21-TON continuous mixing machine, called a Ko-Kneader is shown open with the 16-ft. stainless steel mixing screw being lifted out for cleaning. Built by the Chemical Machinery Div. of Baker Perkins, the machine is the largest produced by the company.

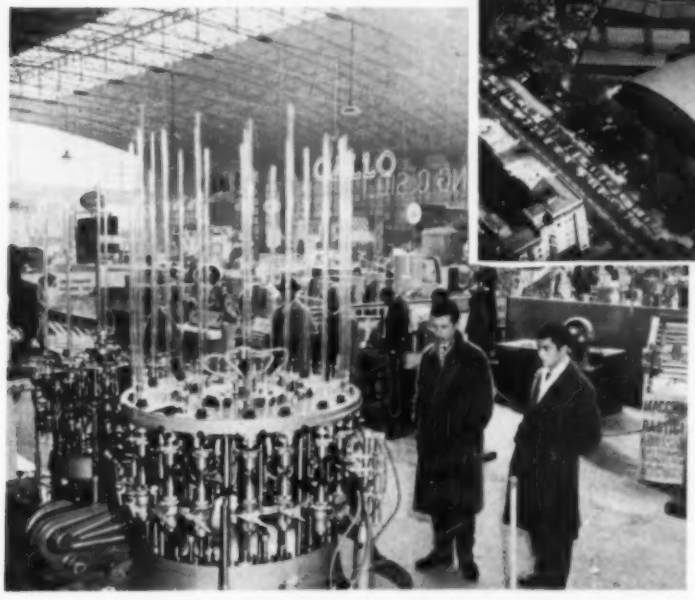


THE NEW RESEARCH reactor of SORIN (Societa Ricerche Impianti Nucleari), jointly owned by Montecatini and Fiat, will carry out basic and applied nuclear research programs for the two companies, will also produce radioisotopes.



THIS NEW SULFURIC ACID PLANT in Riverton, Wyoming, will double the sulfuric acid capacity of Wyoming. Built by Susquehanna-Western, Inc., a subsidiary of the Susquehanna Corp., the plant will produce 75,000 tons of acid a year. Operated by the parent company, the plant is fully automated.

MILAN TRADE FAIR, held annually, is said to be the largest combined industrial, commercial and agricultural show in the world. Last year (below) 4,300,000 people saw more than 1,000,000 products from 120 countries.



Industrial Expositions —Worldwide focus

Here are only two of the growing number of science and trade expositions across the world—one over, one projected.

AIChE Petrochemical and Refining EXPOSITION

SOME EIGHTY PERCENT of the petrochemical plant capacity in the U. S. is located along the Gulf Coast site of the upcoming Petrochemical and Refining Exposition sponsored by A.I.Ch.E., February 26-March 1, 1961.

chemical feature

Acrylic paints set to venture outdoors

Boom predicted in water-soluble coatings as result of improved resistance to sunlight, perfected application methods.

PRODUCERS OF ACRYLIC MONOMERS, as well as acrylic emulsion manufacturers, are betting on a walloping boom this year in do-it-yourself paint jobs. Reason for the optimism—formulators now feel that they have licked the twin bottlenecks in use of water-based paints for outside work, resistance to sunlight and adhesion, particularly to wood surfaces which have been coated before.

Every problem in use of the water-based paints on exterior wood surfaces has not yet been solved, warn the paint makers:

- New wood surfaces must always be coated with a primer (usually oil or alkyd-based) before putting on the water-based paints;
- Existing finishes should generally be removed completely before repainting.

The paint makers say, however, that it won't be long before they will be marketing (and guaranteeing) water-based coatings that can be applied over old outside paint jobs, as oil-based paints are today.

Other hazards with the water-based latex paints, according to the principal makers, are the facts that latex paints should not be applied when the temperature is below 40°F, and that certain woods used in house construction contain water-soluble stains which can penetrate the latex coatings.

Advantages

On the plus side of the ledger are several definite advantages claimed by the latex paints over conventional oil-based varieties:

- They have better resistance to ultraviolet light, that is, they discolor less rapidly in the sunlight;
- They will not blister—acrylic-based paints transmit a certain amount of water vapor, a kind of "breathing";
- Durability seems good—makers claim up to two or three times the life of oil-based paints;
- They are quick-drying—successive coats can be applied after a very short time interval.

Market estimates differ

Estimates of future market potential for water-based paints in general, and acrylics in particular, swing over a wide range. From present consumption estimates of about 100,000 gallons a year for all exterior latex paints, some prognosticators foresee a rise to 20 or 30 million gallons within a decade. Others, more optimistic, set the figure nearer 50 million gallons. (Present sales of all water-based paints, chiefly for interior use, are estimated at around 70 million gallons).

At present, the market for water-based paints is dominated by butadiene-styrene and polyvinyl acetate formulations. The outlook for styrene–butadiene latexes is definitely down, while the future seems bright for the acrylics and the polyvinyl acetates. One of the major producers predicts that, within five years, polyvinyl latexes will be composed of about ⅔ copolymers and ⅓ homopolymers—mostly acrylates.

Four routes

Four major U.S. producers of the basic acrylic monomers use four different processes, different raw materials to arrive at essentially the same goal.

Celanese has adopted the Goodrich process which starts with the oxidation of butane. Ketene and formaldehyde are reacted to form beta-propiolactone, which is then reacted with alcohol in the presence of acid to come out with acrylate esters.

Rohm and Haas uses the "superimposed stoichiometric" process, which is essentially a modification of a basic process worked out in Germany by Walter Reppe. Here, acetylene, carbon monoxide, ethyl or methyl alcohol, nickel carbonyl, and hydrogen chloride are reacted together in a continuous "semicatalytic" process.

Union Carbide Chemicals starts with ethylene oxide (of which it is a large-scale producer). This is reacted with hydrogen cyanide to form ethylene cyanohydrin. Subsequent hydrolysis and esterification lead to acrylic esters.

Fourth variation is that adopted by Dow Badische, based on direct esterification of acrylic acid, which is initially made from acetylene, carbon monoxide, and water according to a process also due to Reppe.

Methacrylates

What is thought to be the only commercial-scale process employed in the U.S. for methacrylates is used both by Rohm and Haas and Du Pont. Developed by ICI (England), the process is based on the reaction of acetone cyanohydrin and sulfuric acid to form methacrylamide sulfate, which is then reacted with methanol to come out with methyl methacrylate.

Escambia Chemical, however, has announced plans to pilot a process involving oxidation of isobutylene with nitrogen oxides to give alpha-hydroxyiso-butyric acid, which would then be dehydrated to methacrylic acid. Direct esterification would then produce methacrylate esters.

Wide range of uses

Coatings, while they represent a major source of market potential for the acrylics, are by no means the only promising outlet.

Applications of cast sheet, first developed for use in military aircraft, have continued to expand. In addition to use in civilian jet planes, such uses as window glazing and skylights in architectural applications have grown significantly.

Other outlets for the emulsions include the finishing of leather, paper products, and floor polishes.

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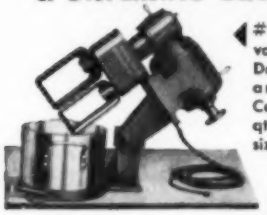

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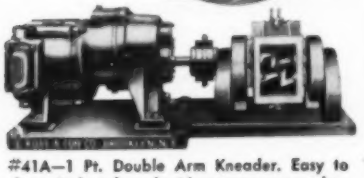

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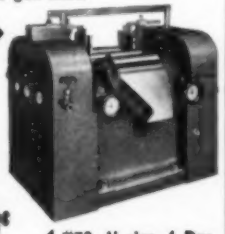

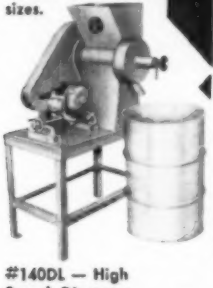

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Candidates

from page 131

Koppel, Lowell B., *Chicago, Ill.*
Kovach, Ronald M., *Columbus, Ohio*
Lasseter, Thomas E., *Freeport, Texas*
Leach, G. L., *Pasadena, Texas*
Leban, Mark, *Chicago, Ill.*
Leland, Roger, *Texas City, Texas*
Locke, Carl E., *Ponca City, Okla.*
Low, Tommy R., *Batesville, Ark.*
Macnn, John W., *Cosmopolis, Wash.*
Marks, Robert E., *Atlanta, Ga.*
McGuire, Billy Gene, *University City, Mo.*
McLees, Carl E., *Baytown, Texas*
McMahon, George J., *Chicago, Ill.*
Miller, Glen E., *Pampa, Texas*
Montgomery, Keith M., *Lakewood, Ohio*
Mulcahy, Jerry L., *San Mateo, Calif.*
Mullen, Charles V., Jr., *Cactus, Texas*
Nimmo, Robert A., *Freeport, Texas*
Pelletier, Raoul C., *Orono, Maine*
Piker, James S., *Texas City, Texas*
Preusser, Robert H., *Brooklyn, N. Y.*
Randolph, Kendall B., *Framingham, Mass.*
Rogers, Martin, *Gary, Ind.*
Roselius, Don D., *Sequin, Texas*
Roth, Charles J., *Port Arthur, Texas*
Ruusi, John H., *Ishpeming, Mich.*
Ryan, Daniel J., *Chester, Pa.*
Schmitt, David A., *Racine, Wisc.*
Schoepf, Edward L., Jr., *Westtown, N. Y.*
Scott, Robert D., *Niagara Falls, N. Y.*
Small, Richard G., *Avon Lake, Ohio*
Srimani, B. N., *Calcutta, India*
Tait, Thomas Michael, *Houston, Texas*
Tamm, Heino, *Chicago, Ill.*
Timmins, Tom H., *Houston, Texas*
Tischer, Robert L., *Dayton, Ohio*
Truitt, James K., *Beacon, N. Y.*
Turner, Robert H., *Merchantville, N. J.*
Turner, Ronald J., *Cuyahoga Falls, Ohio*
Turpin, Jimmy, *Little Rock, Ark.*
Van Mynen, Ronald, *S. Holland, Ill.*
Vinson, C. G., *E. Orange, N. J.*
Wang, Richard S. H., *Orange, Texas*
Wascheck, Charles J., *Newark, Del.*
Wharton, Willard H., *Orange, Texas*
Yates, Harvey C., *Lincoln Park, Mich.*

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Hudson, H. E., Jr., *New York, N. Y.*
Smith, Edward W., *Philadelphia, Pa.*
Steenkamer, Henry B., *Beaumont, Texas*
Watkins, R. N., *Decatur, Alabama*

A geon vinyl plastic material plant now under construction at Altona, Australia, is B. F. Goodrich Chemical's seventh overseas venture. Raw material for the $4½ million unit will come from the petrochemical operations of other companies in the area. Goodrich and C. S. R. Chemicals of Sydney, Australia, are joint owners of the operating company.

A $1¼ million nitric acid plant with a rated capacity of 120 tons a day, placed on stream at Lawrence, Kansas, for the Cooperative Farm Chemicals Assn., was built by Chemical Construction, New York. The nitric acid will be used to make ammonium nitrate fertilizer for the midwestern farm region.

Start-up of a new unit has boosted by 25 million pounds the furnace carbon black annual capacity of Continental Carbon. The Westlake, facilities also include a 45 million pound-a-year unit, built in 1951.

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local sections

Chicago one-day meeting

The spotlight was turned on computers at the highly successful One Day Symposium held by the Chicago Section on February 23. A concurrent four-paper technical session devoted to economics and the engineer, was also manned by experts from leading firms.

A practical example of how Goodrich applied computer control at its Calvert City plant was presented by J. M. Madigan, development scientist. Madigan took the wraps off some of the technical details surrounding a project in which an RW 300 computer scans, logs, and controls a vinyl chloride process involving thermal pyrolosis of ethylene dichloride to vinyl chloride and hydrogen chloride. The unit will soon take on acrylonitrile production. **(Madigan's paper will be printed in its entirety in the May issue of CEP.)**

The session on computers was led off by C. R. Hall, Du Pont, with Prospects for Computer Controlled Processes From a Chemical Engineer's Viewpoint. The economic aspects of the subject were covered by K. Knoblauch, manager, chemical markets, Minneapolis-Honeywell Regulator. At present, he said, there is a tendency to assume that digital computer controlled processes are a black box which can save money. But computers must be matched with the process, and this will require more cooperation between the manufacturer and the buyer. Marrying Computer and Process Instrumentation, V. V. Tivy, wound up the session.

Engineering economics

Kick-off on the subject of Economics and the Engineer was by W. J. Diltz, financial and investment analyst. He talked about the engineer from the investor's viewpoint. The part played by financial matters and economics in the work of a chemical engineer was further pointed up by an advertising, executive, Peter Franz, Leo Burnett Co. He aptly titled his speech, Taking the Mystery out of Marketing. How Chemical Technology Fits into the Over-all Economic Picture was covered by James E. Mitchell, Jr., manager economic evaluation, Dow Chemical. The Summing

Up, by James B. Weaver II Atlas Powder, rounded out the session.

Leader of the program on computers was John C. Vaaler, editor of Chemical Processing. The discussions on economics were moderated by W. D. McEachron, Standard Oil (Indiana). Banquet speaker was R. C. Gunness, executive vice president, Standard Oil, Indiana.

Central Ohio

A progress report on process optimization in the chemical industry was featured at the January meeting of the **Central Ohio Section** (*James D. Jackson*). Edward P. Bartkus, Du Pont, explained that present engineering graduates are being trained in this technique. He feels that the best prep-

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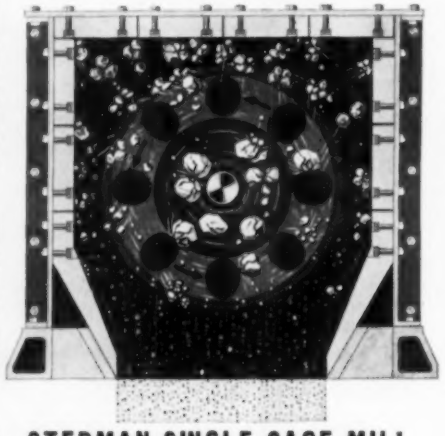

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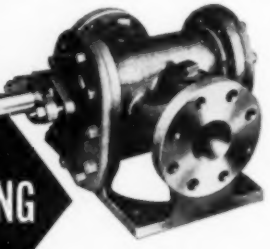

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aration for engineers already in industry is a planned review beginning with algebra. This systems engineering approach to select the best overall process from the results of research and development, studies of plant locations, and investment and operating costs, will be used to a greater extent as we become more proficient in the application of mathematical models.

Twenty-four chemical engineering students from Ohio State University were guests of the local chemical industry at the meeting.

New clubs

Recent developments on the organizational front: A **Long Island** group, taking in New York's Nassau and Suffolk Counties, recently elected officers. Herbert Thompson Jr., Chas. Pfizer, is chairman. Other officers are John B. Tooker, Murray Zelenetz, Anthony Sengakis, and Cecil Chilton.

The **Western North Carolina Chemical Engineer Club** elected their first slate of officers at the January meeting. J. C. Randall, Olin Mathieson, is chairman. R. J. Lombardo, J. E. Anderson and T. F. Hanna are other officers.

A chemical engineers club formed in **Western Oregon** in February looks forward to becoming a full fledged Section.

Also meeting

A run-down on the history of chemical engineering was featured at the **North Jersey Section** in March. Warren L. McCabe, administrative Dean, Polytechnic Institute of Brooklyn, and former president, A.I.Ch.E., was the speaker. The meeting was held at the Newark College of Engineering, as part of its 75th Anniversary celebration . . . The significance of research trends in electronics for the chemical industry was H. W. Leverenz' topic at the **New Jersey Section** March meeting. He is director of research, RCA Laboratories . . . Evolutionary operation as a statistical tool for achieving higher efficiencies from industrial processes was discussed by Herbert F. Kraemer, Ethyl Corp., at the **Southwest Louisiana** (*Robert L. Goodkind*) February meeting. The section, along with AIEE, Louisiana Engineering Society, American Military Engineers, and the local college's McNeese Engineering Society, heard Lt. Col. Loyd G. Coutts talk on human resources, also in February . . . B. F. Dodge of Yale, a past-president of A.I.Ch.E., spoke on salt water processing at the **Maryland Section.**

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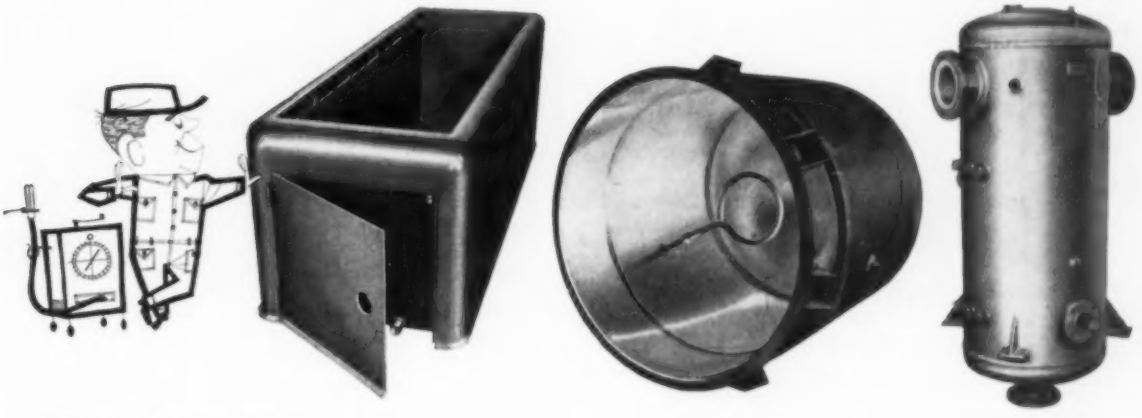

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Best Atlanta Presentation Award Goes to J. M. Smith

J. M. Smith is winner of the Award for Best Presentation of paper at the National A.I.Ch.E. meeting held in Atlanta, February 21-24. Professor and chairman of the Chemical Engineering Department at Northwestern University, he was honored for delivery of the paper, *Diffusion Rates in Porous Catalysts*.

Smith joined the faculty of Northwestern in 1957, after three years in the Chemical Engineering Department at Purdue University. There, he also worked as assistant director of the Engineering Experiment Station. A graduate of California Institute of Technology, he received an ScD from MIT in 1943.

Smith was in private industry for several years, holding posts as research engineer at Standard Oil of California, and at Monsanto. During World War II, he was on the National Defense Research Committee.

Fulbright scholar

The recipient of both a Fulbright Award and a Guggenheim Fellowship, Smith studied in the Netherlands as a research scholar during 1953 and 1954. A profilic contributor to technical journals, he is author of over fifty articles. He also wrote Introduction to Chemical Engineering Thermodynamics, and Chemical Engineering Kinetics.

Others mentioned

The Atlanta Meeting Awards Committee gave honorable mention to four others for paper presentation. They are: **J. D. Fleming,** Georgia Institute of Technology; **W. A. Samuel,** Callery Chemical; **J. R. Martin,** Case Institute of Technology; and **L. J. Polite, Jr.,** Diamond Alkali.

Ray E. Fiedler takes over as manager of Archer-Daniels-Midland Soybean Division. His headquarters will be in the company general offices at Minneapolis.

Morton Salkind has been named vice-president, Sam J. Gallay Advertising, New York. Salkind was associate editor for Chemical and Engineering News. He was formerly account executive at Molesworth Associates.

J. W. Scott takes over at California Research's Richmond Laboratory as division superintendent, petroleum process development.

William M. Creasy, Major General, U. S. Army, retired, a vice president of the Lummus Company, has been appointed manager, New York Division. Creasy, who joined the company in 1958, had served as chief chemical officer of the Army since 1954. In this post, he was in charge of the

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Army Chemical Corps. He was also adviser to the Secretary and Chief of Staff of the Army, the Navy, Air Force and other defense agencies. Creasy has an MS in chemical engineering practice from MIT, and received training at the Chemical Warfare School, and the Army-Navy Staff College.

S. Z. Avedikian, takes over as acting director of Lummus' Engineering Development Center in Newark. Avedikian, the holder of about thirty U. S. and foreign patents, recently returned from several months in Europe. There, his process for manufacturing sodium hydrosulfite has gone into operation at the Dutch firm, N. V. Koninklijke Nederlandsche Zoutindustrie. Co-founder of S. Z. Avedikian Associates, he also established Tidings Corporation of America in 1947.

Charles A. Stokes has joined Columbian Carbon as general manager, research and development, Carbon Black and Pigment Division. Stokes, who has had extensive experience in carbon black and petrochemical research, comes to Columbian from Texas Butadiene and Chemical. He served on the teaching staff of MIT, and studied there and at the University of Florida. Stokes will have his headquarters at the Columbian Research Laboratories, Princeton, New Jersey.

John Lewis has been named technical director, Pulp & Paper Research Centre, Lawrence, Mass. Former head of the Paper Engineering Department, Lowell Technological Institute, he had been with them since 1952. He also taught at the University of Maine, as associate professor of chemical engineering in the Pulp and Paper Section.

R. D. Sheeline has been appointed to the newly established solid propellant application group in the Solid Propulsion Section at Rocketdyne, (North American Aviation). **R. S. Levine** was named chief, Physical Processes Section.

continued on page 140

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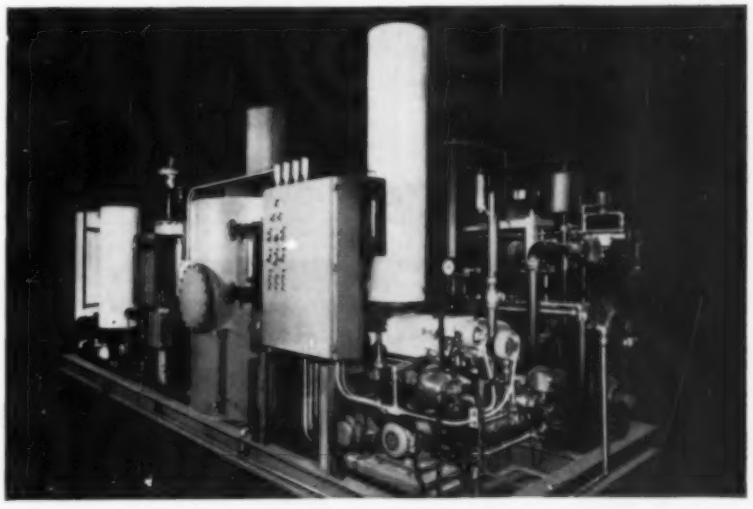

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People

from page 139

John T. Pinkston has been elected a vice president of United Engineers & Constructors. He will continue as process consultant and head up the firm's activities for the gas industry. A patent holder, Pinkston has published technical papers dealing with developments in petroleum refining and chemical processing.

Ernst W. Thiele retired from Standard Oil Company (Indiana) as development coordinator at the Whiting research laboratories. Thiele joined the company in 1925, after obtaining his PhD from MIT. While at MIT, he developed the McCabe-Thiele method for calculating distillation problems. He has played a major part in nearly all areas concerned with developing methods for refining petroleum, particularly catalytic cracking. Thiele has served as government adviser in atomic energy, including work on the Manhattan project. His future plans are for university teaching; in September, he will be visiting professor of chemical engineering at Notre Dame.

Marketing

Curry E. Ford moves up to the post of director of marketing for National Carbon (Union Carbide). With the company since 1937, he held the position of new products marketing manager for the last three years. Ford will handle the company's complete line of industrial carbon and graphite products. Associated with him will be **W. C. McCosh**, manager, carbon products.

Alan J. Breslau and **Jack Dunnous** have been appointed to the technical staff of Mitchell Specialty Division, Industrial enterprises. Breslau was formerly in charge of urethane foams and epoxy resins at Thiokol Chemical. He also headed the rubber reclaim plant, Essex Rubber.

Robert R. Burns takes over the newly created post of manager, Commercial Development Department, Nalco Chemical. A graduate of Oklahoma A&M, Burns has been with the company since 1956.

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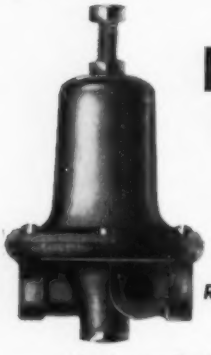

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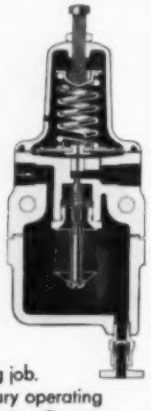

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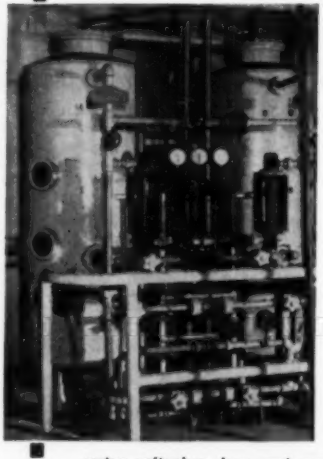

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J. H. Rines has been advanced at Pitts-Consol Chemical to the post of manager, rubber chemical sales. **L. E. Welch** is manager, procurement. Both men joined the company in 1956. Rines, a Cornell graduate, formerly was connected with B. F. Goodrich Chemical. Welch was vice president, Industrial Hard Chromium, was with the Office of Scientific Research and Development while with Bakelite Corp. during World War II.

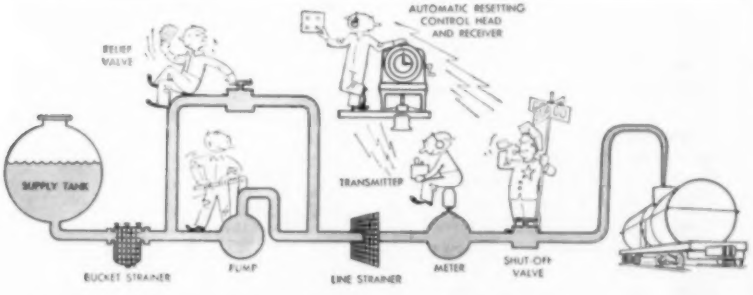
Frank M. Macioce takes over as regional sales manager, Industrial Filter & Pump Mfg. With Industrial for ten years as sales engineer, Macioce has been engaged in design of Ion exchange and waste treatment equipment.

Key executive appointment at American Electronics is **Joseph W. Ranftl**, to the post of marketing manager, Nuclear Division. Ranftl was recently selected as one of twenty-one U. S. Delegates to the International Atomic Energy Agency meeting on Large Radiation Sources in Industry, in Warsaw, Poland. Prior to joining American Electronics, he was with GE for thirteen years.

Necrology

George Armistead, Jr., 58. He was founder and head of George Armistead and Company, consulting engineering firm, since 1945. Located in St. Michaels, Md., the firm acted as consultant to petroleum refiners, chemical, engineering, and insurance companies. Its activities varied from designing many of the Greek government's petroleum and chemical projects, to the investigation of the Texas City disaster which killed 561 persons in 1947. Armistead is the author of numerous publications on refining techniques, economics and industrial safety. He also wrote a textbook on the prevention of loss by fire and explosion in the petroleum and chemical industries. Active in A.I.Ch.E., he headed the National Program Committee in 1954-1955. Armistead also was chairman of the National Capitol Section in 1950.

Henry Marx, 101. A former president of G. A. Gray Company, Cincinnati, Ohio, Marx was a charter member of the American Society of Mechanical Engineers. He was the last survivor of a group of engineers who founded ASME in 1880.



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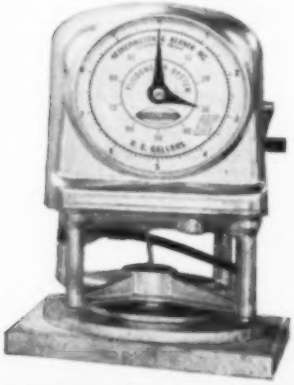

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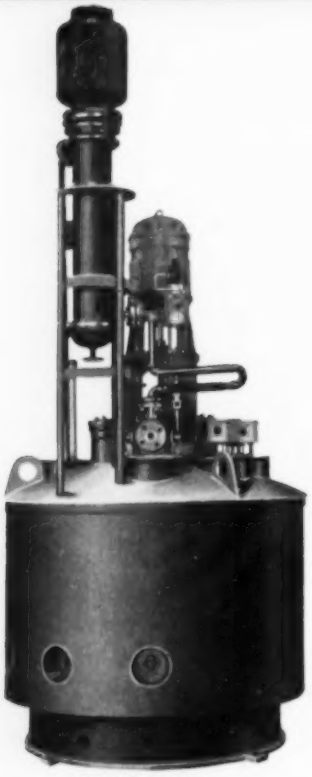

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future meetings

1960—MEETINGS—A.I.Ch.E.

• Mexico City, Mex., June 19-22, 1960. Hotel Del Prado. **Joint Meeting with Instituto Mexicano de Ingnieros Quimicos.** See p. 122.

• Newark, N.J. May 10, 1960. Hotel Essex House. **One-day Joint Technical Symposium New Jersey and North Jersey Sections A.I.Ch.E.** Equipment-Advances in Design and Construction: Commercial Chemical Development. For info: W. A. Schnyder, Hoffman-LaRoche, Inc., Nutley 10, N.J.

• Moscow, USSR, June, 1960. 1st Congress of International Fed., Automatic Control. To cover areas of **Theory, Hardware & Applications of Automatic Control.** U. S. participation sponsored by American Automatic Control Council. Affiliated societies: **A.I.Ch.E., ASME, AIEE, IRE, ISA.** A.I.Ch.E. Chmn.: D. M. Boyd, Universal Oil Prods., Des Plaines, Ill.

• Buffalo, N. Y., Aug. 14-17, 1960. Statler Hilton Hotel. **4th National Heat Transfer Conference & Exhibit. Sponsored by A.I.Ch.E. & ASME.** A.I.Ch.E. sponsored panel discussion on **Discrepancies Between Design Procedure & Plant Operation.** Moderated by D. Q. Kern. Panelists: D. J. Bergman, Union Oil; C. H. Brooks, Sun Oil; C. H. Gilmour, Union Carbide Chem.; A. C. Mueller Dupont. A.I.Ch.E. papers to S. W. Churchill, U. of Mich., Ann Arbor, Mich. ASME papers to J. P. Hartnett, U. of Minnesota, Minneapolis, Minn. Exhibit info to P. A. Joculvar, A.I.Ch.E., 25 West 45 St., N. Y. 36, N. Y.

• Boston, Mass Sept. 7-9, 1960 M.I.T. **Joint Automatic Control Conference.** Sponsored by A.I.Ch.E., AIEE, IRE, ASME, ISA. For A.I.Ch.E. info refer to: W. H. Abraham, Eng. Exp. Sta., Dupont, Wilmington, 98, Del.

• Tulsa, Okla., Sept. 25-28, 1960. Hotel Mayo. **A.I.Ch.E. National Meeting.** Tech. Prog. Chmn.: K. H. Hachmuth, Phillips Petroleum Co., Bartlesville, Okla. **Multiphase Flow in the Production & Drilling of Oil Wells**—L. P. Whorton, Atlantic Refining, Box 2819, Dallas 1, Texas. **Natural Gas & Natural Gas Liquids**—R. L. Huntington, U. of Oklahoma, Norman, Okla. **Advances in Refinery Technology**—W. C. Offutt, Gulf R&D Co., P. O. Drawer 2038, Pittsburgh 30, Pa. **Petrochemicals**—C. V. Foster, Continental Oil Co., Ponca City, Okla. & H. L. Hays, Phillips Chem. Co., Bartlesville, Okla. **Piloting or Why Buy the Restaurant When All You Need is a Meal**—R. E. Weis, Phillips Pet. Co., Bartlesville, Okla. & D. Popovac, Continental Oil Co., Ponca City, Okla. **Corrosion & Materials of Construction**—W. A. Luce, The Duriron Co., P.O. Box 1019, Dayton 1, O., & M. S. Whorley, Black, Sivalls & Bryson, P.O. Box 1714, Oklahoma City, Okla. **Statistics and Numerical Methods Applied to Engineering**—R. L. Heiny, 2709 Jefferson, Midland, Mich. **Air & Ammonia Plant Safety**—G. Weigers, Amer. Cyanamid Co., P.O. Box 10008, Jefferson Branch, New Orleans 21, La. **Refinery & Natural Gasoline Plant Safety**—J. N. Romine, Phillips Petrol., Bartlesville, Okla. **Processing Agricultural Products**—A. Rose, Tex. Eng. Exp. Sta., Tex. A&M, Coll. Sta., Tex. **Chemical Reactions Induced or Modified by Radiation**—J. J. Martin, Ch.E. Dept., U. of Mich., Ann Arbor Mich. **Conservation & Utilization of Water**—F. J. Lockhart, Ch.E. Dept. of U. of So. Cal., 3551 University Ave., Los Angeles 7, Cal. **Foams**—C. S. Grove, Jr., Syracuse U., Syracuse 10, N. Y. & R. L. Tuve, U.S. Naval Rsch. Lab., Wash. 25, D.C. **Computers as a Management Tool**—R. Cziner, Grace Chem. Co., 3 Hanover Square, New York 4, N. Y. **Non-Newtonian Fluid Mechanics**—A. B. Metzner, U. of Delaware, Newark, Del. **Student Program**—O. K. Crosser, Univ. of Oklahoma, Norman, Okla. **Selected Papers**—R. H. Perry, Ch.E. Dept., U. of Oklahoma, Norman, Okla.

Deadline for papers: May 2, 1960.

• Washington, D.C., Dec. 4-7, 1960. Statler Hotel. **A.I.Ch.E. Annual Meeting.** Tech. Prog. Chmn.: D. O. Myatt, Science Communication, Inc., 1079 Wisconsin Ave., N.Y., Wash. 7, D.C. **Air Pollution**—A. J. Teller, U. of Florida, Gainesville, Fla. **Unsteady—State Instrumentation**—T. J. Williams, Monsanto, Chem. Co., St. Louis, Mo. **Fluid Dynamics**—A. C. Acrivos, U. of California, Berkeley, Calif. **Information & Communications**—R. O'Dette, NSF, Wash. D.C. **Nuclear Reactor Operations**—R. L. Cummings, Atomics International, Canoga Park, Calif. **Nuclear Chemical Plant Safety**—C. E. Dryden, Ohio State U., Columbus, O. **Phase Transitions**—O. Bankoff, Northwestern U., Evanston, Ill. **Sales Overseas**—J. Costigan, The Sharpless Corp., 501 Fifth Ave., New York 17, N.Y. **Chemical Engineering—A Vital Link in Broadening the Uses of Agriculture Crops**—J. E. Simpson, U.S.D.A. **Chemical Warfare-Dispersal of Materials in Aerosol Form**—L. E. Garono, Army Chem. Corps. **Role of the Chemical Engineer in Environmental Health Engineering**—W. L. Faith, Air Pollution Foundation, 2556 Mission St., San Marino, Calif. **Feeding, Clothing, and Protecting the Combat Soldier**—Leo Spano, Quartermaster R&Eng. Command, Natick, Mass. **Phenomena Affecting Materials in Extreme Environments**—J. Hearne, Air Force R&Eng. **Impact of Govt. Programs on Chemical Engineering Education**—W. K. Davis, Bechtel Corp. **Toxic Plant Construction**—L. E. Garono, Army Chem. Corps. **Potentialities of Fuel Cells as Power Sources**—P. Greer, Army OOR. **Saline Water Conversions**—J. J. Strobel, OSW, Dept. Int. **Chemical Engineering in the Mineral Industry**—H. Perry, Chf. Bit. Coal Res. Br., U.S. BuMines. **Missiles & Rockets**—W. E. Sheehan, DDRE. **Economic Evaluation of New Processes**—J. H. Hirsch, Gulf R&D Co., P.O. Drawer 2038, Pittsburgh 30, Pa. **Heat Transfer**—M. Altman, Gen. Elect. Co., 3198 Chestnut St., Philadelphia, Pa. **New Crystallization Techniques**—H. M. Schoen, American Cyanamid Co., 1937 W. Main St., Stamford, Conn.

Deadline for papers: July 5, 1960.

1960—MEETINGS—NON-A.I.Ch.E.

• Madrid, Spain, June 5-9, 1960. Instituto Nacional de Industria, Plaza de Salamanca 8. **13th Biennial Sectional Meeting, World Power Conference.** For registration forms & info: Brig. Gen. S. E. Reimel, Secy., World Power Conf., 29 W. 39 St., New York 18, N.Y.

• New Hampton, New London, Meriden (all) N.H. June 13-Sept. 2, 1960. **Gordon Research Conferences** on Coal and Physical Metallurgy-Relation of Structure and Properties. Applications at least 2 months prior to conf. to: W. G. Parks, Director, Chem. Dept., Univ. Rhode Island, Kingston, R. I.

• Boulder, Colo. Aug. 23-25, 1960. **Cryogenic Engineering Conference** spons. by Univ. Colo. & NBS. 200-word abstracts by May 15, on field **below 150° K.** to: K. D. Timmerhaus, Secy., Ch.E.Dept., Univ. Colo., Boulder, Colo.

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1961—MEETINGS—A.I.Ch.E.

• New Orleans, La., Feb. 26-March 1, 1961. Hotel Roosevelt. **A.I.Ch.E. National Meeting.** Tech. Prog. Chmn.: A. L. Regnier, Petroleum Chem., P.O. Box 6, New Orleans 6, La. **Brainstorming Technical Problems**—G. C. Szego, Space Technology Labs., P.O. Box 95001, Los Angeles 45, Calif. **Kinetics of Catalytic Reactions**—M. Boudart, Princeton U., Princeton, N.J. **Petrochemicals—Future of the Industry on the Gulf Coast**—J. A. Sherred, Monsanto Chem. Co., St. Louis 66, Mo. **Filtration**—P. M. Tiller, U. of Houston, Houston, Texas. **Settling**—A. G. Keller, La. State U., Baton Rouge, La. **Future Processing Technology in the Petroleum Industry**—A. F. Kaulakis, Process Res. Div., ESSO. **Education and Professionalism**—R. P. Dinsmore, Goodyear Tire & Rubber Co., Akron 16, O. **Mathematics in Chemical Engineering**—R. L. McIntire, Mathematical Eng. Assoc., 3108 Sweetbriar, Fort Worth 9, Tex. **Evaluation of R&D Projects**—L. A. Nicolai, 239 Parsonage Hill Rd., Short Hills, N.J. **Liquid—Liquid Extraction**—R. B. Beckman, Carnegie Tech., Pittsburgh 13, Pa. **New Petrochemical Processes in the Area**—B. G. Caldwell, Dow Chem. Co., Plaquemine, La. **Materials of Construction**—R. V. Jelinek, Syracuse U., Syracuse, N.Y. **Thermodynamics**—J. J. Martin, Ch.E. Dept., Univ. Calif., L.A. 24, Calif. **Use of Probability Mathematics in Economic Evaluation**—A. G. Bates, Atlas Powder Co., New Murphy Rd., Wilmington 99, Del. **Selected Papers**—E. Mannings, Shell Oil Co., Norco, La.

Deadline for papers: Sept. 5, 1960.

• Cleveland, O., May 7-10, 1961. Hotel Sheraton-Cleveland. **Joint A.I.Ch.E. National Meeting with Ch.E.Div. C.I.C.** Tech. Prog. Chmn.: R. P. Dinsmore, Goodyear Tire & Rubber Co., Akron 16, O. **Petrochemicals as Starting Materials for Polymers**—L. P. Marek, A. D. Little, 30 Memorial Dr., Cambridge 42, Mass. **Fluid Mechanics**—W. H. Gauvin, McGill Univ., Montreal, Que. **Optimum Utilization of Pilot Plants**—J. T. Cumming, School Eng., Fenn College, Cleveland 15, O. **Process Dynamics (Theoretical)**—R. M. Butler, Imperial Oil Co., Sarnia, Ont. **Synthesis Processes for Isoprene**—T. A. Burtis, Houdry Process Corp., 1528 Walnut St., Phila. 2, Pa. **Radioactive Materials for Process Control**—J. R. Bradford, College of Eng., Texas Tech. College, Lubbock, Tex. **Process Dynamics (Applied)**—L. M. Naphtali, Ch.E. Dept., Brooklyn Polytech., Brooklyn, N. Y. **New Synthetic Rubber Types**—P. M. Lindstedt, Goodyear Tire & Rubber Co., Ch.E.Div., Akron 16, O. **Coalescence**—R. Kintner, Illinois Inst. Tech., Chicago 16, Ill. **Management Criteria for Capital Investment**—C. F. Prutton, Food Machy. & Chem. Co., 161 E. 42 St., New York 17, N. Y. **Ch.E. in Metal Refining**—W. M. Campbell, Chem. & Met. Div., Atomic Energy of Can., Chalk River, Ont. **Heavy Metal Mfr.**—L. P. Scoville, Diamond Alkali, Union Commerce Bldg., Cleveland 14, O. **Applications of High Speed Photography**—A. I. Johnson, Univ. Toronto, Toronto 5, Ont. **General Papers**—D. J. Porter, Diamond Alkali, P. O. Box 348, Rsch. Center, Painsville, O. **Student Program**—H. B. Kendall, Case Inst., 10900 Euclid Ave., Cleveland, O.

Deadline for papers: Dec. 7, 1960.

• Lake Placid, N. Y., Sept. 24-27, 1961. Lake Placid Club. **A.I.Ch.E. National Meeting.** Tech. Prog. Chmn.: E. R. Smoley, 30 School Lane, Scarsdale, N. Y. **Process Management; Commercial Chemical Development; Sales Engineering.**

• New York, N. Y., Dec. 3-6, 1961. Hotel New Yorker. **A.I.Ch.E. Annual Meeting.** Tech. Prog. Chmn.: A. V. Caselli, Shell Chem. Corp., 50 W. 50 St., N. Y. 20, N. Y. **Heat Transfer; Management; New Processes; Nuclear Engineering; Water Pollution; Process Dynamics; Pilot Plants; Fundamentals; Petroleum & Petrochemicals; Fluids; Fluidization; Sublimation; Adsorption; Student Program.**

1962—MEETINGS—A.I.Ch.E.

• Los Angeles, Calif., Feb. 4-7, 1962. Hotel Statler. **A.I.Ch.E. National Meeting.** Tech. Prog. Chmn.: G. C. Szego, Space Technology Labs, Inc., P.O. Box 95001, Los Angeles 45, Calif.

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CHEMICAL ENGINEER—M.S. Eight years' experience. Seek responsible challenging work in development, design, technical service on plant or pilot plant scale. Prefer metropolitan area, will consider foreign employment. Box 7-4.

PRODUCT ENGINEER—Ph.D.Ch.E., with diversified experience solicits sponsored research (1) from raw material suppliers seeking greater participation in the water thinned paint industry and (2) from manufacturers requiring improved formulations. Box 8-4.

B.S.Ch.E.—Age 30, experience in patents, application preparation and prosecution; knowledge of organic chemistry including polymers. Desire patent position, technical writing, industrial sales, location immaterial. Box 9-4.

CHEMICAL ENGINEERING PROFESSOR—Desire consulting association full time during summer and part time during academic semesters. Eighteen years' experience in propulsion, heat transfer, nuclear engineering and technology, kinetics and catalysts, distillation process development and engineering. Box 10-4.

GENERAL MANAGEMENT POTENTIAL — Chemical engineer, 36, desire position to qualify for management. Thirteen years' one company. Strong production background, process and project management, staff headquarter administration. Not production oriented. Knows need for all-function balance. Present income $15,400. Box 11-4.

CHEMICAL ENGINEER—Sales manager or sales engineer position desired. B.Ch.E., 1951. Nine years' experience, four in process plant start-up and field service, five as sales engineer industrial and corrosion equipment. Present salary $10,500 plus bonus. Will relocate. Box 12-4.

CHEMICAL ENGINEER — M.S.Ch.E. Have nineteen years' engineering and supervisory experience in petroleum refinery equipment design, construction and maintenance to trade for opportunity in engineering management or consulting field. West or foreign only. Box 13-4.

B.Ch.E., M.S. IN MANAGEMENT—Age 34, married, children. Desire interesting position with future possible. Salary secondary to potential, environment, and good management. Prefer process development, production, quality control. Present salary $9,000. Box 14-4.

RESEARCH & DEVELOPMENT — Presently, staff assistant to Research Director. Formerly, Section Head, process development. Experienced in project appraisals, evaluating new project proposals, technical-economic feasibility studies, liaison with other departments. Heavy experience in chlorination metallurgy. Ph.D., Ch.E. Age 39. Experience, eleven years' industrial, six and one half teaching. Seeking a more responsible position. Box 15-4.

CHEMICAL ENGINEER—B.Ch.E., 1956, MBA, 1960. Three years' chemical engineering and business experience, including management training program; also Purchasing Agent responsibilities for small chemical firm. Interested in developing responsibilities in marketing, production or purchasing. Box 16-4.

CHEMICAL ENGINEER—B.S., M.S. 1954. Six years' experience in process improvement, production and economic analysis of processes. Desire challenging opportunity in similar areas. Previous supervisory experience. Fluent Spanish. Prefer eastern location but would consider other areas including foreign assignments. Box 17-4.

DEVELOPMENT ENGINEER—Five years' broad experimental and analytical experience in nuclear field, including development of advanced heat transfer concepts, design of research and component-testing equipment, and statistical experiment design. New York area preferred. Box 18-4.

(continued on page 146)

PRODUCTION MANAGER ASSISTANT

Successful medium-size company has unusual opportunity for capable engineer to advance into management position. Must have degree in chemical engineering or chemistry. Should have at least five years experience in organic chemical manufacturing operations, preferably working with dyestuff—sulfur or other classes, at plant supervisory level. Knowledge of quality and cost control desirable, also production and equipment maintenance. Must be willing to relocate at our expense to pleasant small Southern community. All replies strictly confidential. Local interviewing if necessary. Please give full information about yourself including age, education, experience and present salary. Write Box 2-4.

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Has Through Promotions and Expansion, Two Important Openings for Promotable Young Men.

PROCESS ENGINEER

for **evaluation, selection** and design of our process equipment. Ch.E. degree with 3-5 years applicable experience with either **processors** or **engineering construction firms** will be suitable. Work involves diversified processes with a variety of unit operations and widely divergent conditions.

ASST. PLANT ENGINEER

for **supervision** of the **maintenance** function and the personnel involved. M.E., Ch.E., or Pet.E. degree with 3-5 years supervisory maintenance experience in **petroleum** or **chemical processing** required.

If you feel prepared to step up to the responsibilities described above please write in confidence with full information to:

John W. Church
Personnel Manager
Armour Industrial Chemical Co.
110 N. Wacker Drive
Chicago 6, Illinois

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AviSun Corporation, a newly organized affiliate of American Viscose Corporation and Sun Oil Company, is a fully integrated company interested in all polyolefinic materials. Major interests are now in research, development, manufacture, processing and marketing of polypropylene polymer, fibers, and films.

Chemical engineers with B.S. or M.S. degrees and 0-8 years of related experience are especially needed for process development or product development studies of fibers or films.

Work location is in Suburban Philadelphia at Marcus Hook. Real opportunities to grow professionally or administratively are already evident. Interested engineers are invited to send full particulars concerning their personal history, education, and work experience to:

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Attention: William M. Nolan—AviSun

Project Engineer—Chemical Engineer—For process design, maintenance and construction supervision in small, expanding, progressive chemical company. Excellent opportunity for ambitious, capable young man with diversified background. Prefer 3 to 8 years experience in petroleum or chemical process industries. Salary commensurate with experience and ability. Send resume and list references with first letter to: **Great Lakes Chemical Corp., Filer City, Michigan.**

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ARAMCO seeks to employ 1960 grads for our training program who are interested in Process, Project, Construction or Design Engineering and/or process operations. Initial assignment may be in New York office prior to assignment in Saudi Arabia, where the company is engaged in producing and refining crude products. Excellent community facilities with modern family housing. Salary conducive to savings, plus all-inclusive benefit plan.

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BECHTEL CORPORATION
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SITUATIONS WANTED
A.I.Ch.E. Members

(continued from page 144)

CHEMICAL ENGINEER—B.Ch.E., 1955. Age 28, married. Five years' diversified experience in Design and Plant Technical. Desire responsible, growth position in process engineering or production with opportunity to advance administratively. Eastern location. Box 19-4.

CHEMICAL ENGINEER—M. S. 1951, honors. Senior process design engineer, nine years' experience in process design and development, economic evaluation, start-up, operations, staff work (determination of incentive, scheduling, budget, policies and procedures, etc.). Desire staff work as assistant to executive in company where my work can have some significant effect. Present salary $11,000. Family. Box 20-4.

CHEMICAL ENGINEER—B.S. Twelve years' diversified experience, applied research, engineering, technical service, quality control. Fertilizer specialist. Practical and business minded. Accept responsible management position. Prefer midwest or midsouth location. Box 21-4.

CHEMICAL ENGINEER—M.S.Ch.E. (1949), P.E. Age 34. Ten years' experience includes process design, control and development, works engineering, planning and scheduling, in nuclear power, explosives, acids, fermentation. "Q" clearance. Desire responsible position in process or project engineering. Prefer West Coast location, will consider others. Box 22-4.

CHEMICAL ENGINEER—M.S.Ch.E., 1955. Four years' organic chemical production, including plant research and development, engineering, construction, maintenance. Age 28, single, desire overseas position, preferably Europe. Others considered. Box 23-4.

SENIOR POSITION — requiring exceptional combination of technical competence and economics background sought by Ph. D. (chemical engineer), M. A. (economics). Fifteen years' experience in R & D chemical plant problems. Experienced group leader with responsibility for large projects, strong organizational ability. Box 24-4.

PROCESS ENGINEER—Nineteen years' experience in process design, economic analysis, long-range planning, process development, and initial operation of petrochemical plants and oil refineries. Responsible charge of projects for engineering contractors and supervisory experience over plant engineering department for major chemical company. Desire responsible position with operating company or engineering contractor. Eastern U. S. only. Box 25-4.

CHEMICAL ENGINEER — B.S.Ch.E., M.S.I.E. Four years' diversified experience in economic evaluation, process design and improvement, plant construction and start-up. Seek responsible and challenging position in production or process engineering with growth potential. Will relocate. Box 26-4.

CHEMICAL ENGINEER—36, Sc.D., M.I.T. Experience in process development, design, teaching and research. A dozen patents in inorganic processes. Looking for a challenging position in process development, engineering research or design. Box 27-4.

CHEMICAL ENGINEER—M.S.Ch.E., P.E., age 41. Fifteen years' experience in process and plant design; product and process research and development; technical and economic feasibility. Good knowledge of engineering science plus sound appreciation of profitability. Desire responsible position with growth potential. Box 28-4.

CHEMICAL ENGINEER—B.S.Ch.E., Age 26, family. Four years' experience in development and production technical assistance in petrochemical and inorganic industries. Desire position in production or development. Any location except east and south. Box 29-4.

RESEARCH DIRECTOR—B.S.Ch.E. 1942. Age 38. Twelve years' diversified experience in hardboard research and development. Looking for challenging position as Research or Technical Director of progressive company in southeast or southwest. $12,000. Box 30-4.

CHEMICAL ENGINEER—M.S., age 30. Experienced in process economic evaluations. Working group leader in lab and pilot developments and in successful plant start-ups and improvements. Broad experience with unit operations and process control including high energy fluids. Seek responsibility with small company and opportunity to express ideas. Box 31-4.

(continued on page 152)

PRODUCT APPLICATIONS *specialist*

Expansion of our special products line and new research developments have created a need for us to employ a man who is experienced in new product applications development.

Requirements are a Bachelor's degree, including marketing and science courses, with particular interest in chemistry or paper technology, and at least two years' experience in new product development work in either the chemical or paper industry.

The work involves—

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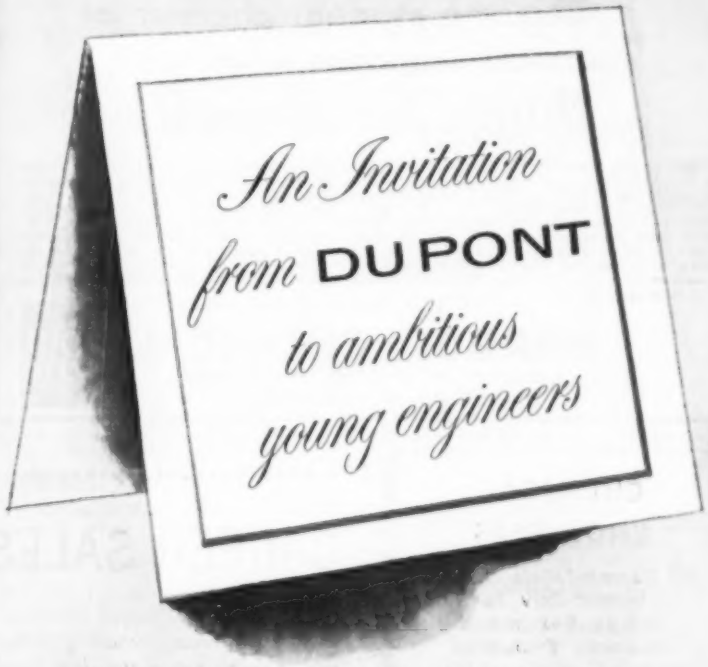
Medium sized midwestern manufacturer well known for 42 years of successful operation in the automotive components field has opening for qualified man experienced in compounding of highly developed synthetic polymers. Duties will encompass the planning and supervision of development projects which will lead to direct product applications. The work offers real challenge and opportunity for personal growth. Complete laboratory facilities available. Excellent hospitalization, pension and profit sharing plan. Salary commensurate with background and experience.

Box 41-4

PROCESS ENGINEERS—BS, MS, PhD in ChE, ME or EE



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Mr. William M. Redd, Jr., Engineering Department

E. I. du Pont de Nemours & Co., Inc.
Wilmington 98, Delaware

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chemical process engineers

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Bartow, Florida

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EMPLOYE RELATIONS DIRECTOR

SEMET-SOLVAY PETROCHEMICAL DIV.

ALLIED CHEMICAL CORP.

40 Rector Street **New York 6, N. Y.**

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MILES LABORATORIES, INC.
1127 MYRTLE STREET
ELKHART, INDIANA

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Due to a recently announced expansion program, the Ohio plant of the Vinyl Resins Division of a nationally known rubber and chemicals manufacturer seeks chemical engineers. Applicants must have three to four years of production, development or process control experience.

Polymerization background desirable. Excellent advancement potential. Send resume of education and experience, stating salary requirements. All replies held in strict confidence. Write Box 4-4.

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Major Company is developing an extensive diversification program calling for a wide variety of top-level talent as follows:

1. Chemical or petroleum refining process design, project development and/or operation.
2. Air separation plant design and operation or related cryogenic experience.
3. Hydrocarbon extraction design or operation experience.
4. Engineering Economic evaluation.

Prefer minimum of five years experience applicable to any one or combination of above.

Address replies with full resume in complete confidence to:

BOX 5-4

CHEMICAL ENGINEER

Excellent opportunity with progressive manufacturing concern located in New Jersey for graduate engineer, under 35 with 5 to 8 years experience in development and process design. Strong background in mathematics, mass and heat transfer desired. Must be well grounded in thermo-dynamics. Prefer men with Master's Degree interested in position with wide potential but requiring initiative and ability in getting jobs completed.

Submit resume stating full particulars.

BOX 40-4

Allied Chemical

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Expanding operations create unusual opportunities for chemical engineers with experience in chemical and plastics manufacturing industries.

Positions are available at various levels of experience in process design, economic evaluation, and engineering studies.

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K. D. Meiser
Assistant Director of Engineering
Plastics & Coal Chemicals Division

ALLIED CHEMICAL CORPORATION
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Send resume to:

Lawrence C. Lacy
PERSONNEL DEPARTMENT

THIOKOL CHEMICAL CORP.
HUNTSVILLE, ALABAMA

(continued on page 152)

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2—Louisville rotary dryers, 8' x 50', SS
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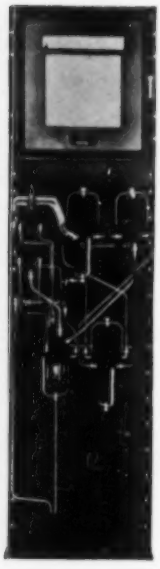

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(continued from page 150)

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(continued from page 146)

M.S.Ch.E.—Wishing to pursue doctoral program seek research or academic position permitting such study. Ten years' varied research and academic experience. Presently Associate Professor in accredited department. Age 34. Box 35-4.

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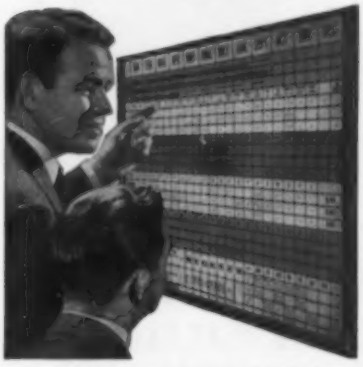

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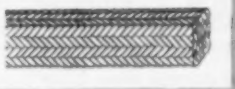

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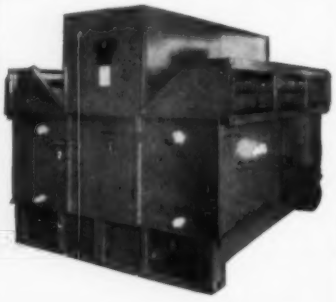

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News and Notes of A.I.Ch.E.

United Engineering Center—A.I.Ch.E. is still active in the campaign to enlist funds for the United Engineering Center. Members know that ground has been broken and that at present it is estimated that we shall move into these new headquarters around July of next year. One Local Section of A.I.Ch.E. is at present discussing donating $1,000 from the section's treasury for the U.E.C., and last year the Washington-Oregon Section with headquarters at Seattle voted to contribute to the center as a memorial to Arthur T. Walton, a member of

the chapter who was killed in an automobile accident. Lyle J. Gordon of the Scott Paper Company and George L. Hagen of Reichhold Chemicals wrote to us about this.

The total U.E.C. fund now stands at $7,888,485.80. A.I.Ch.E. and the American Institute of Consulting Engineers are the only societies at present that have met the quotas assigned them, but the other societies are getting very close, and officials of the center are optimistic about meeting the financial goal. A recent newsletter from the Member Gifts Committee had the following quotation: "We would like to contribute $10 toward the UEC. Although this is a small amount, it represents a considerable portion of our treasury. We feel that some day we as national members may use the UEC and that now is the time for the I.E.'s to stand up and be counted as a professional group." —from a letter sent by Ernest W. Mander, AIIE Student Chapter President, University of Massachusetts.

New Chemical Engineers Group—Bob Moen of Oregon State College writes that the Oregon Chemical Engineers Club was formed in February at Salem, Oregon, and agreed unanimously to apply for Local Section status as soon as requirements have been met. K. W. Bird is secretary, and P. L. Pringle made all arrangements for the meeting. Moen writes that forty-five engineers attended the organization meeting . . . *Welcome.*

Nominating Committee—The Nominating Committee for 1960 is headed by Past-President Donald L. Katz. On the Committee with him will be E. B. Christiansen of the University of Utah, D. A. Dahlstrom of The Eimco Corporation, G. L. Farrar of the *Oil & Gas Journal,* W. B. Franklin of the Humble Oil & Refining Company, J. G. Knudsen of Oregon State College, and J. L. Olsen of the Sun Oil Company.

For Local Sections wishing to send suggestions to the Nominating Committee or to back a petition, here is the all-important schedule that must be met if their candidates are to get maximum publicity. The bylaws of A.I.Ch.E. require that the Nominating Committee complete its slate of officers and directors at least 20 weeks

before the Annual Meeting in order that the candidates may be publicized in CEP. The Nominating Committee's suggestions will be submitted, therefore, by July 15 and will appear in the August issue of CEP.

Although the constitution requires that nominating petitions be received in this office not later than 9 weeks prior to the Annual Meeting—or by October 2—my advice to all sections considering backing a favorite candidate by a petition is to try, in fairness to the candidate, to get biographical data, picture, etc., along with the petition signed by the required fifty members, into A.I.Ch.E. headquarters not later than July 15. Otherwise there can be no guarantee that the nominees by petition will appear in the August issue with the candidates selected by the Nominating Committee.

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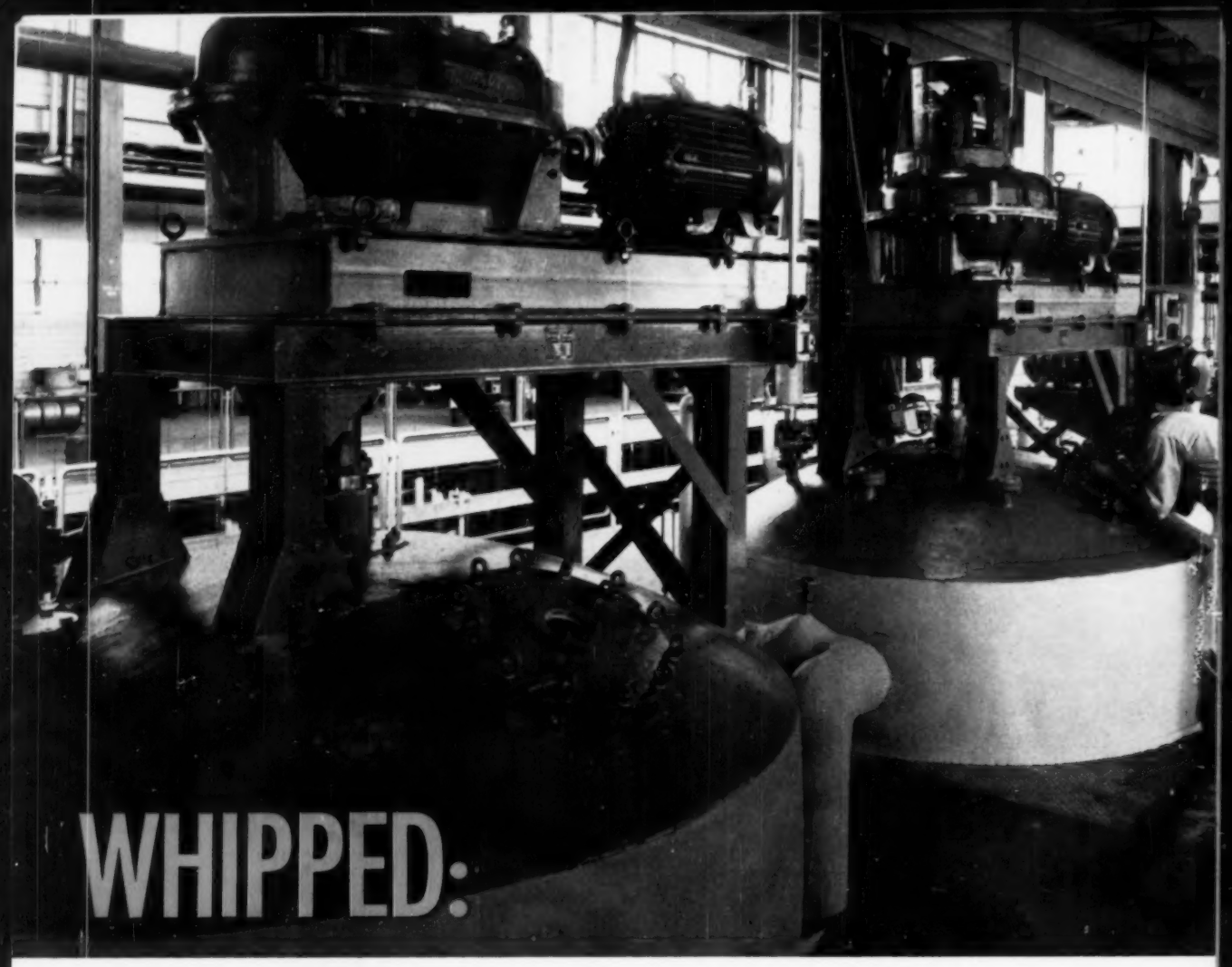

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